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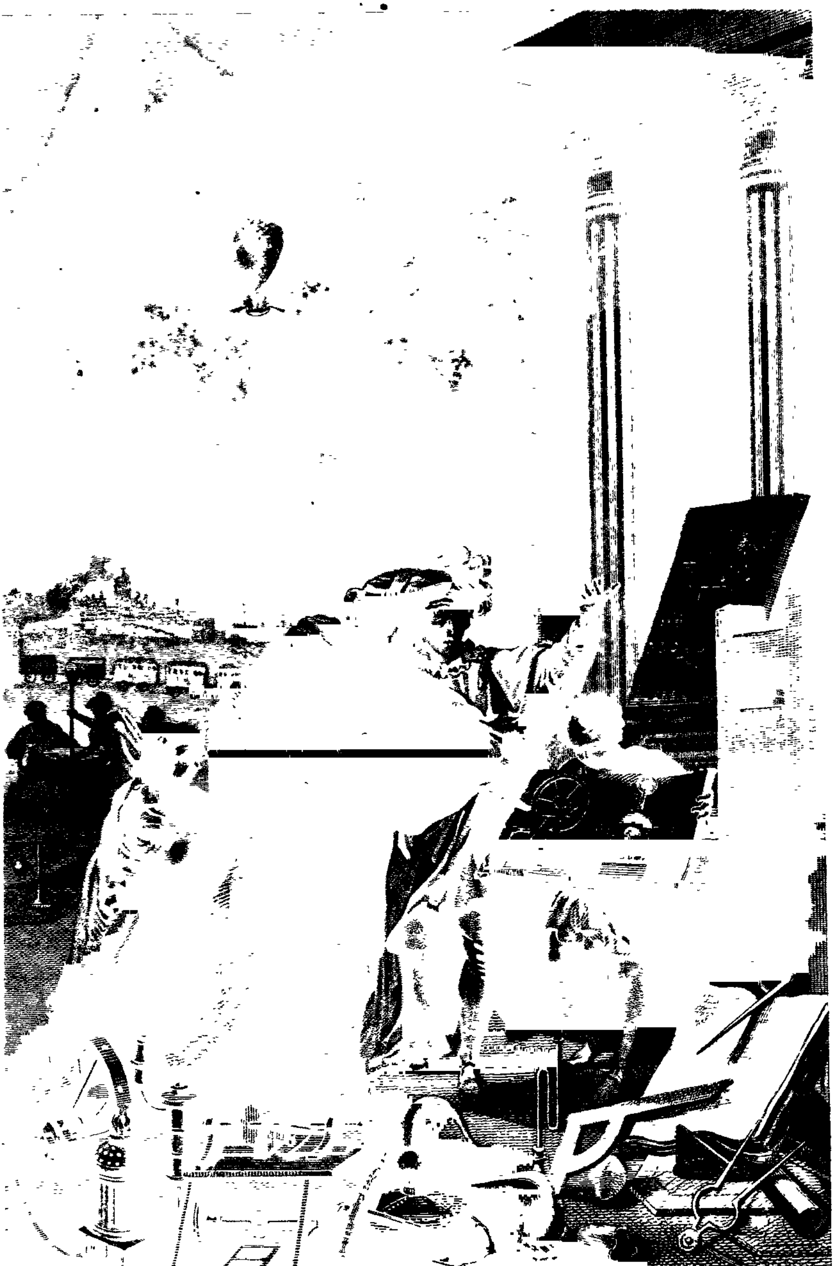

ENGINEER'S AND [illegible]

ENCYCLOPÆDIA.

THE

ENGINEER'S AND MECHANIC'S

ENCYCLOPÆDIA,

COMPREHENDING

PRACTICAL ILLUSTRATIONS

OF

THE MACHINERY

AND

PROCESSES EMPLOYED IN EVERY DESCRIPTION OF MANUFACTURE

OF THE

BRITISH EMPIRE.

With nearly Two Thousand Engravings.

BY LUKE HEBERT,

CIVIL ENGINEER;

EDITOR OF THE HISTORY AND PROGRESS OF THE STEAM ENGINE, REGISTER OF ARTS, AND JOURNAL OF PATENT INVENTIONS, ETC.

IN TWO VOLUMES.

VOL. I.

"How much useful knowledge is lost by the scattered forms in which it is ushered to the world! How many solitary students spend half their lives in making discoveries which had been perfected a century before their time, for want of a condensed exhibition of what is known!"—BUFFON.

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PREFACE.

ALTHOUGH many excellent treatises have been published on the THEORY of the Mechanical and Chemical Sciences, none of them embrace a combined and *general* view of the PRACTICAL APPLICATION of those sciences to the operative arts and manufactures of the Empire. There are, however, it must be admitted, several meritorious works which treat *partially* on these subjects; but to the objection of their contracted plan, may be added that of an inconvenient arrangement for ready reference; and the practical information that may be sought for in the voluminous Cyclopædias of Science and Literature, though attainable only by laborious research, is, in most instances, so abstruse or antiquated, as to be of no utility to those who are desirous to avail themselves of the best combinations of inventive skill, or to practise the new processes resulting from modern chemical discovery.

The numerous applications to me, (in my professional capacity of a patent agent,) by inventors, for information on these subjects, demonstrate the foregoing fact, and fully convince me of the great advantages that would be conferred upon a very extensive and influential portion of the community, by the publication of a work which should embrace a judicious selection of all those MACHINES, ENGINES, MANIPULATIONS, PROCESSES, and DISCOVERIES, that now lie scattered throughout several hundred volumes of the scientific journals, or are inscribed in obsolete characters upon the rolls of the Court of Chancery, in the form of specifications of patent inventions.

To accomplish an undertaking of such great convenience to the scientific, as well as of real utility to operative men, in a form *adapted to instant reference and ready application*, has been my chief aim in the present work, which will comprehend, in addition to the usual matter contained in cyclopædias on the mechanical and chemical sciences, upwards of two thousand modern inventions and discoveries of merit and originality, illustrated by Engravings carefully executed from accurate working drawings.

Notwithstanding the extent and variety of subjects which this work embraces, it may be necessary to remark, that by the adoption of a small type, and close printing, the economy of space is so far attained as to admit of each subject receiving the consideration due to its importance, and to comprise the whole in two thick octavo volumes. Thus, the preparation and numerous manufactures of that invaluable metal, the indispensable material of our machinery, (IRON) has received particular attention: so have, likewise, the various manipulations and mechanism employed in our great staple commodities, COTTON, SILK, WOOLLEN, and LINEN. The construction of ENGINES (particularly STEAM ENGINES), MILLS, RAILWAYS, CARRIAGES, SHIPS, BOATS, DOCKS, CANALS, BRIDGES, FURNACES, BOILERS, GAS MACHINERY, LOOMS, PRESSES, PUMPS, PADDLES, PLOUGHS, STILLS, WATCHES, CLOCKS, WATER-WORKS, WHEELS, CRANES, STOVES, and a thousand other subjects, receive, in like manner, their share of attention. The various important processes of DYEING, DISTILLING, BLEACHING, BREWING, TANNING, and numerous other chemical manufactures, present also conspicuous features in the contents of this work, the whole of which may be said to combine an exposition of the entire series of the Mechanical and Chemical Arts of the British Empire.

LUKE HEBERT.

PATERNOSTER-ROW,
November 1, 1835.

THE

ENGINEER'S AND MECHANIC'S

ENCYCLOPÆDIA.

ABACA. A kind of flax, which grows in the Philippine Islands. There are two varieties of it, the white and the grey; the former is used in the fabrication of fine linen, and the latter chiefly for cordage.

ABACUS. An instrument employed to facilitate arithmetical calculations. The name was given by the ancients to a table strewed with dust, on which their mathematicians were in the practice of drawing their diagrams. Similar tables are employed in our Lancasterian schools, for teaching children to write. The abacus employed by the ancient Greeks for making calculations was, it is said, similar to the "counting machine" sold in our toy and stationary shops, for teaching the rudiments of arithmetic. It consists of twelve parallel wires, fixed in a light rectangular frame, each wire carrying twelve beads, or balls. There are thus 12 times 12, answering to the common multiplication table, all the results of which it demonstrates to the dullest capacity; and by moving the beads from one side to the other, the operations of addition or subtraction are rendered clear and obvious to the juvenile student.

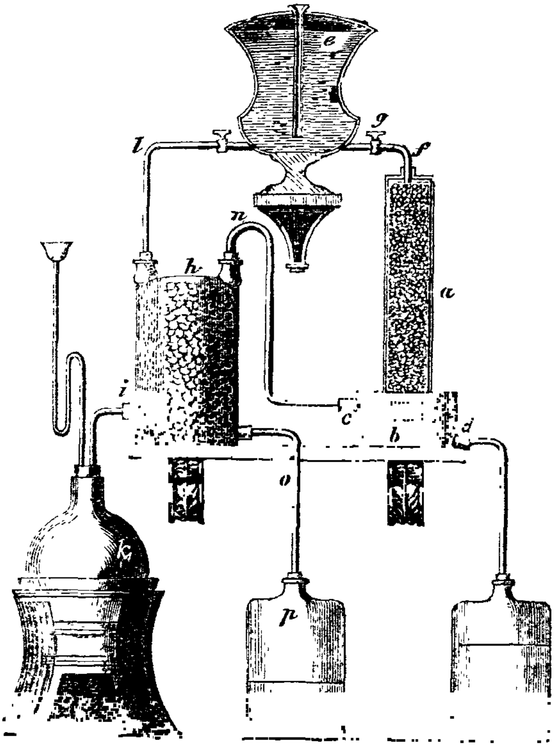
ABACUS. In architecture, the level, tile-shaped tablet, formed on the capital of a column to support the horizontal entablature.

ABRASION. The act of tearing, or wearing away the surface of any substance by rubbing. See FRICTION.

ABSORB; from the Latin verb, *absorbeo,* signifying to suck in. When a solid body combines with one that is fluid, and the compound remains solid, the solid is said to have absorbed the fluid; and the solid in this case, likewise, becomes an *absorbent.* In common language, we say, sugar absorbs water; but this is not strictly correct, for in proportion as the water is taken up, the sugar is dissolved. Sponge is, however, a perfect absorbent. In like manner liquids absorb æriform matters; thus, water absorbs carbonic acid gas; charcoal, and other porous solids of a fibrous texture, have the faculty of absorbing the gases in a remarkable degree.

ABSORBING AND PRODUCTIVE CASCADE. An apparatus of great utility and elegance, invented by M. Clement. It is known that the absorption or solution of the gases takes place in proportion to the pressure on the absorbing liquid, the extent of surface exposed to the absorbing action, and to the length of time in which it is exposed. If the pressure, however, be very great, the vessels are liable to rupture; and it therefore becomes an important object to strengthen the influence of the other two principles just mentioned, which has been obtained in a very eminent degree by the invention of M. Clement. In this apparatus, which is represented in the annexed diagram, the gas has no pressure to sustain, but the surfaces of its contact are exceedingly multiplied and extended

The column *a* is filled with a great number of small bulbs of glass or porcelain, its lower extremity resting in another cylinder *b*, of greater diameter, in which is a cavity adapted to the reduced diameter of the column, which communicates with two small tubes *c*, *d*, the former being employed to introduce the gas, and



the latter to discharge the liquid. At *e* is a reservoir of water, with a conducting pipe *f*, the supply therefrom being regulated by a cock *g*. The water, in its passage to the lower part of the column, successively moistens all the small spheres, and being thus impeded in its progress, a very considerable time is occupied in its descent. On the other hand, the gas, as it is introduced, occupying all the vacant interstices, becomes infinitely divided; and therefore as it can only pass through the intermediate spaces very slowly, the duration of the contact is much prolonged, and the absorption promoted. The inventor calculates that the absorbing power of this apparatus is 322 times greater than the ordinary simple vessels used for the purpose. Although M. Clement, in making this comparison, has unquestionably selected the most unfavourable case, it must be admitted that his absorbing cascade possesses great advantages. To the apparatus thus described, M. Clement adapts another, which he calls "the Productive Cascade," shown in combination in our diagram. It is intended to produce gas for a considerable period of time, and in a more convenient and less expensive manner than by the ordinary methods. Suppose, for example, it is required to prepare oxymuriatic acid or chlorine; a large vessel *h*, provided with four openings, is filled with oxide of manganese, broken into large pieces; the opening *i* is by a tube connected to a leaden vessel *k*, containing common salt and sulphuric acid. By the tube *l*, a small stream of water is made to flow from the reservoir above, which gradually moistens the whole surface of the pieces of manganese, and permits the muriatic acid gas to attack

and dissolve it very easily. The chlorine which is produced, passes by the tube *n*, into the absorbing cascade, while the muriate of manganese is carried off as it forms, by the water, through the tube *o*, into the reservoir *p*. By this arrangement, there is no occasion to reduce the manganese to powder, and a much larger quantity may be operated on at the same time, without the operator being under the necessity of frequently renewing the charge of materials, and dismounting his apparatus.

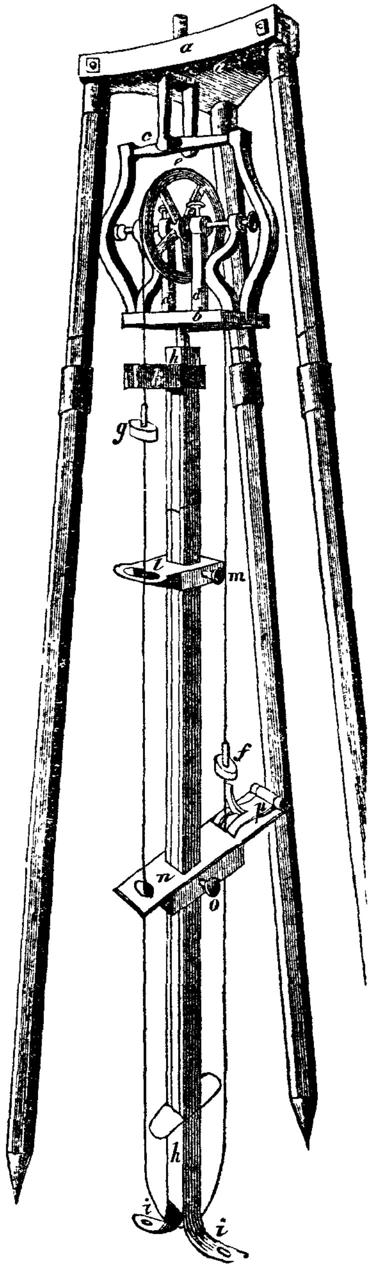
ABUTMENT, in Carpentry, means the joining or meeting of two pieces of timber, of which the fibres of the one extend perpendicularly to the joint, and those of the other parallel to it. See Nicholson's "Practical Builder." In Civil Architecture, the term is applied to that which receives the end of, and gives support to, any thing having a tendency to spread or thrust outwards. When the arches of a bridge are less than semicircles, or less than semi-ellipses, the parts which they thrust or rest against, are termed abutments. If the arches are complete semi-circles or semi-ellipses, or other formed arches that spring from a vertical line, they are piers or imposts. The extremities of a bridge are, however, always termed abutments; that is, abutments of the bridge itself, on the ground, that the roadway may be considered an outer arch, whose abutments are the land piers. The term abutment is likewise much used by engineers, to express those fixed parts of mechanism from whence a resisting or reacting force is obtained. Thus each of the ends of the cylinder of a reciprocating steam engine form reacting points for the pressure of the steam, causing the piston to be impelled the contrary way. In a rotary engine, the steam stop is the abutment; in a screw-press, the stationary head through which the screw passes, is also an abutment.

ACCELERATION is the increase of velocity in a moving body, caused by the continued action of the motive force. When bodies in motion pass through equal spaces in equal times, or, in other words, when the velocity of the body is the same during the period that the body is in motion, it is termed uniform motion, of which we have a familiar instance in the motion of the hands of a clock over the face of it; but a more correct illustration is the revolution of the earth on its axis. In the case of a body moving through unequal spaces in equal times, or with a varying velocity, if the velocity increase with the duration of the motion, it is termed accelerated motion; but if it decrease with the duration of the motion, it is termed retarded motion. A stone thrown up in the air, affords an illustration of both these cases, the motion during the ascent being retarded by the force of gravity, and accelerated by the same during the descent of the stone. All bodies have a tendency to preserve their state, either of rest or of motion; so that if a body were set in motion, and the moving force were withdrawn, the body, if unopposed by any force, would continue to move with the same velocity it had acquired at the instant the moving force was withdrawn. And if a body in motion be acted upon by a constant force (as the force of gravity), the motion becomes accelerated, the velocity increasing as the times, and the whole spaces passed through increasing as the square of the times; whilst the proportional spaces passed through during equal portions of time, will be as the odd numbers, 1, 3, 5, 7, &c.; and the space passed over in any portion of time, will be equal to half the velocity acquired at the end of such time, which results will be better brought to view in the following Table.

Times.	Velocities.	Spaces for each Time.	Total Space
1	1	1	$1=1^2$
2	2	3	$3+1=4=2^2$
3	3	5	$5+3+1=9=3^2$
4	4	7	$7+5+3+1=16=4^2$

It has been ascertained by experiment, that a body falling freely by its own weight from a state of rest, will descend through $16\frac{1}{12}$ feet in the first second of time, and will have acquired a velocity of $32\frac{1}{3}$ feet; but from the rapidity with which the velocity increases, we cannot extend the experiment, for in only four seconds, a body falling freely would pass through a space of 256 feet. But by

an ingenious contrivance of the late Mr. Attwood, of Cambridge, the laws of motion above laid down may be verified experimentally. The machine is called "Attwood's machine," after the name of the inventor; and the principle of its action consists in counteracting a portion of the gravitating power of a body, by the gravitating power of a smaller body; so that the absolute velocity, and the spaces passed through, shall be less than in the case of bodies descending freely, whilst, as the force is constant, the same ratio of progression will hold in both cases. The annexed figure represents one of these machines, as constructed by Mr. Toplis. *a a a* is a triangular frame, upon three moveable legs; *b*, a small platform suspended from it by a universal joint *c c*, and supporting two upright standards *d d*, in which the axis of a light brass wheel *e* revolves with very little friction. Over a groove in the periphery of the wheel, passes a very light and pliable silk thread, from the ends of which hang two equal weights *f*, *g*. Into the under side of *b* is screwed a square rod *h*, descending to the floor, to which it is secured, in a perpendicular position, by small pins passing through holes in the claws at *i i*. On the face of the rod is a scale of inches. *k* is a brass guide, fixed at the upper part of the rod *h*, so that when the top of the weight *g* touches the lower side of *k*, the under side of *g* is on a level with the top, or commencement of the scale; *l* is a small stage, movable along the rod *h*, and having a hole in it sufficiently large for the weight *g* to pass: on one side is a tightening screw *m*. *n* is another movable stage, fitted with a tightening screw *o*, as also a fork *p*, turning upon a hinge. The experiments are conducted as follows:—A small circular weight is placed upon *g*, which is pulled up to the top of the scale, and the stage *n* is screwed to the rod *h*, on a level with the lower part of the weight *f*, which is held down upon it by the fork *p*. Upon releasing *f* from the fork, the weight *g* descends with a slow, but gradually accelerated motion, and the number of inches the weight has descended, at each successive beat of a pendulum (suspended from another triangle) is observed upon the scale; and if the additional weight be such as to cause *g* to descend through three inches in the first second, then it will cause it to descend through 1 foot in two seconds, and through 6¼ feet in five seconds. If the additional weight be



removed, and a small bar of equal weight, but of a length exceeding the diameter of the hole in *l*, be placed upon *g*, and the stage *l* be set at any division of the scale, at which the weight would arrive at the end of any number of seconds, the stage will intercept the bar in its descent, and the weight will continue to descend with the velocity it had acquired upon reaching *l*. Thus if the velocity at the end of the second second be two feet, in which case the weight would have descended one foot in that time, if the stage be set at one foot upon the scale, it will intercept the bar at the end of the second second, and the weight *g* will move with a uniform velocity of two feet per second, through the remaining portion of its descent. If it is required to illustrate the case of retarded motion, the small circular weight is placed upon the weight *g*, and a similar small weight upon the weight *f*, so that *g*, still outweighing *f*, will descend; but as soon as the stage *l* intercepts the bar with the small weight upon it, *f* becomes the heaviest, and *g* will descend with a velocity decreasing as the squares of the times, counted from the time of *g* passing the stage *l*. To diminish as much as possible the friction of the axis of the wheel *e*, which carries the line from which the weights hang, Mr. Attwood, instead of causing the axis to turn in fixed bearings, supported it upon the peripheries of four anti-friction wheels, fixed upon the ends of two spindles placed parallel to each other, and as close together as the diameters of the wheels would allow. The sliding or rubbing motion of the axis of the wheel *e*, is by this means transferred to the spindles of the anti-friction wheels, (for the axis does not slide, but it rolls over their peripheries,) and the amount of the friction becomes diminished in the proportion of the diameter of the axis of the wheel *e*, to the diameter of the anti-friction wheels. This is an extremely beautiful and effectual arrangement, but requires great care and nicety of execution; it also enhances greatly the cost of the instrument. Mr. Toplis's method of supporting the axis of the wheel is less complex and costly, whilst it is attended with very little friction, owing to the extremely small quantity of rubbing surface. His plan is as follows: the axis consists of a short piece of steel, not equal in length to the distance between the two standards, between which it is supported. In each end of the axis a conical recess is formed, terminated by a short cylindrical one; these conical recesses receive the ends of two studs or pivots, supported by the vertical standards, and formed into cones more acute than the conical recesses. By this means the rubbing surfaces are reduced to a mere line, forming a species of knife-edge support; the axis is kept steady by the different obliquities of the external and internal cone; and the end of the pivot cannot wear down, as it does not reach the bottom of the cylindrical part of the recess. For the sake of portability, the legs of the triangle, and the square rod *h*, are jointed in the middle, and the wheel, stages, &c. can be packed separately in a small case. Altogether we think Mr. Toplis has rendered the instrument much more portable, and less liable to injury, whilst he has very much diminished the cost without impairing its efficiency.

ACERIC ACID. A peculiar acid, said to exist in the juice of the maple. It is decomposed by heat, like the other vegetable acids.

ACETATES. The salts formed by the combination of the acetic acid with alkalies, earths, and metallic oxides. See their different bases, and the article, ACID, ACETIC.

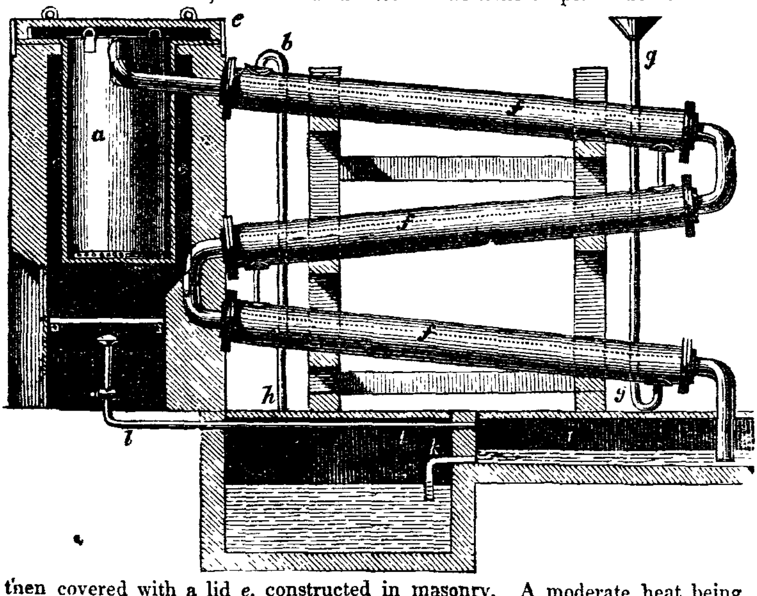
ACETIC ACID. See ACID, ACETIC.

ACHROMATIC. A term applied to those lenses of telescopes, and other optical instruments, in which the aberrations of light common to ordinary lenses are remedied, and the colours justly reflected.

ACIDS. A most important class of chemical compounds, which have for the most part the following properties. They have a sour, or sourish taste, the stronger kinds being acrid and corrosive. They change the vegetable blues and purples to a bright red. They unite with water in almost every proportion. With a few exceptions, they are decomposed or volatilized by a moderate heat. They combine with all the alkalies, and most of the metallic earths and oxides, and form with them that class of bodies termed salts. The varieties of acids are extremely numerous, and will be generally noticed under the head CHEMISTRY The four principal acids of commerce, viz. the acetic, suphuric, nitric, and

muriatic, which are manufactured on the great scale, we shall describe in this place.

ACID, Acetic, is the acid contained in common vinegar, but in a very dilute state, and in combination with other vegetable principles. It is found united with potash in a great variety of plants, also in several animal secretions. It is likewise the result of a spontaneous fermentation, to which liquid, vegetable, and animal matters, are liable. Strong acid, as the sulphuric and nitric, develop the acetic, by their action on vegetables. Dry vegetable substances generally, when subjected to a red heat in close vessels, yield it copiously. The proportion of the products varies not only from employing different substances, but they are different when only one substance is employed, according as the heat is greater or less, or the operation is differently managed. When a vegetable substance is distilled in close vessels, at first the water comes over which existed ready formed, and then water formed by union of the oxygen and hydrogen of the substance. Afterwards, a quantity of carbon is separated; and by the continued application of heat, this unites with the oxygen and hydrogen, and forms an acid, formerly supposed to be a particular acid, and then called pyroligneous acid, but it is now known to be the acetic acid, united with empyreumatic oil, which rises somewhat brown, and grows thicker and darker, augmenting in density as the quantity of carbon increases. At the same time, a small quantity of carbonic acid gas, much carburetted hydrogen, and towards the close, a great quantity of gaseous oxide of carbon, are disengaged. All the carbon not carried off in these various forms, remains in the still, and generally preserves the form of the vegetable substance employed. Since we have learned the nature of all these products, the process has been much improved, and particularly by charring the wood, and by turning the other products to advantage. In the forests, the wood is first charred, so as to dissipate all the water of vegetation. t is then introduced into a large circular vessel *a*, made of iron plates rivetted together, and having at its upper part a small lateral iron cylinder; an iron cover is closely fitted to this pot, and then it is lifted by means of a crane, or other mechanical power, and placed in a cast iron retort *c*, set over a furnace of the same shape. The furnace is



then covered with a lid *e*, constructed in masonry. A moderate heat being applied to the furnace, at first the vapour of the wood is dissipated, but this vapour soon ceases to be transparent, and becomes sooty. At this time a

tube or cylinder, enclosed in another of brick-work or tiles, is affixed to the lateral cylinder, and forms the condensing apparatus. This is different in different places: in some, the condensation is effected by the air, the vapour being made to pass through a long extent of cylinders, and sometimes of casks, adapted to each other; but most generally the condensation or cooling is effected by water, when it can be procured in sufficient quantities. The most simple apparatus for this purpose consists of two cylinders *f f*, enclosed one within the other, and having between them a space sufficient to allow a large quantity of water to flow backwards and forwards, and thus cool the vapour. These cylinders are adapted to the distilling apparatus, and placed inclined to the horizon. To this first apparatus a second, and sometimes a third is adapted, and placed in a zig-zag form, in order to occupy as little space as possible. The water is made to circulate in the following manner. At the lower extremity *g*, of the condensing apparatus, there is a tube which ought to be somewhat higher than the upper part of the whole of this apparatus, where at *h* there is another short tube curved towards the ground. Water from a reservoir is made to run through the perpendicular tube to the lower part of the condensing apparatus, and fills all the space between the cylinders. When the operation is going on, as the vapours are condensed, they raise the temperature of the water, which becoming lighter in consequence, flows out of the curved tube *h*. The condensing apparatus terminates in a covered brick canal *i*, underground, at the end of which is a bent tube *k*, that conducts the liquid products into the first cistern; when this is full, it discharges itself by means of a syphon into a large reservoir; the tube which terminates the canal, plunges into the liquid, and thus cuts off the communication with the interior of the apparatus. The gas hereby disengaged, is conveyed by means of the tube *l l*, under the ash-hole of the furnace. This tube is furnished with a cock, to regulate the flow of the gas, and cut off the communication at pleasure. That end of the tube which terminates in the ash-hole, rises a few inches perpendicularly, and is furnished at its extremity with a perforated rose, for distributing the gas uniformly under the vessel, without being itself liable to become choked with the ashes, or to obstruct the feeding of the fire. The degree of heat necessary to effect carbonization is not very great, yet, towards the end of the process it must be raised sufficiently to make the vessel red-hot, and the length of the operation is necessarily regulated by the quantity of wood to be carbonized at the time. By the colour of the gas flame it is ascertained when the carbonization is complete; at first it is of a reddish yellow colour, but afterwards it becomes blue, as it throws off more oxide of carbon than carburetted hydrogen; at last it becomes entirely white, probably caused by the vessel being hottest at this period, and the combustion, therefore, may then be considered as quite finished. There is also another method of ascertaining the completion of the operation, which is more frequently had recourse to; that is, the cooling of the upper part of the tubes, which is not surrounded with water; some drops of water are then thrown upon it, and if these evaporate without noise, the operation is considered to be finished. The adapting short tube is next removed from the vessel, and the opening into it immediately closed by an iron-plate cover, which is then luted with loam. The lid which covers the furnace is next removed, and then the vessel itself is lifted out of the furnace by means of the crane, which should be immediately replaced by another similar retort got ready for the purpose. When the retort which has been taken out has become cold, it is uncovered, and the charcoal taken out. Whatever may be the kinds of wood employed in this operation, nearly the same results are obtained, as far as respects the acid; not so, however, with regard to the charcoal. The denser the wood, the better the charcoal; and it has been remarked, that when the wood has been long left in contact with the open air, the charcoal produced from it is of a much worse quality than from that wood which is carbonized the same year it was cut. A more simplified arrangement of apparatus than the foregoing, employed for this purpose by an eminent manufacturer in Glasgow, is described by Dr. Ure, in his Chemical Dictionary. It consists of a series of cast-iron cylinders, about 4 feet diameter, and 6 feet long, which are built horizontally in brick-work, so that the flame of one furnace may play

around two cylinders. Both ends are made to project a little from the brick-work. One of them is provided with a disk of cast-iron accurately fitted to it, and from the centre of this proceeds a tube about 6 inches in diameter, that enters the main tube of refrigeration. The diameter of this tube may be from 9 to 14 inches, which will vary according to the number of cylinders. The other end of the cylinder, which is called the mouth of the retort, is closed by a disk of iron, smeared round its edges with clay lute, and made fast by means of wedges. The charge of wood for a cylinder of the before-mentioned dimensions, is about 8 cwt. The hard woods, oak, ash, birch, and beech, are alone used. Fir does not answer. The heat is kept up during the day-time, and the furnace is allowed to cool during the night. Next morning the door is opened, the charcoal removed, and a new charge of wood introduced. The average product of crude vinegar, called pyroligneous acid, is 35 gallons. It is much contaminated with tar, is of a deep brown colour, and has a specific gravity of 1.025. Its total weight is therefore about 300 lbs. The residuary charcoal is found to weigh no more than one-fifth of the wood employed. Hence nearly one-half of the ponderable matter of the wood is dissipated in incondensible gases. The crude pyroligneous acid is rectified by a second distillation in a copper still, in the body of which about 20 gallons of viscid tarry matter are left from every 100. It has now become a transparent brown vinegar, having a considerable empyreumatic smell, and a specific gravity of 1.013. Its acid powers are superior to those of the best household vinegar in the proportion of 3 to 2. By re-distillation, saturation with quicklime, evaporation of the liquid acetate to dryness, and gentle torrefaction, the empyreumatic matter is so completely dissipated, that on decomposing the calcareous salt by sulphuric acid, a pure, perfectly colourless, and grateful vinegar rises in distillation. Its strength will be in proportion to the concentration of the decomposing acid. It is a common error to regard the production of vinegar from the distillation of wood as a recent discovery. In the *Miraculum Mundi* of Glauber (who has given his name to a well-known description of salts), he says, "If this juice of wood be rectified, it may be used in the preparation of good medicines; in mechanic arts; in the making of many fair colours from the extraction of metals, minerals, and stones; and for all things for which common vinegar is used; yea, far more commodiously, because it much exceedeth common wine and beer vinegar in sharpness." Glauber mentions some other applications of the acid which have yet to find their way into modern practice. "If hop-poles," he says, "be dipped in the oil, it not only preserves them, but fattens the plant; and as insects abhor these hot oils, if they be applied to the bark of fruit trees, it will defend them from spiders, ants, canker-worms, and other insects; by this means, also, rats and mice may be prevented from creeping up hovel posts and devouring the grain!" An acetic acid of very considerable strength may also be prepared by saturating perfectly dry charcoal with common vinegar, and then distilling. The water easily comes off, and is separated at first, but a stronger heat is required to expel the acid. If vinegar be exposed to very cold air, or to a freezing moisture, its water will be separated in the form of ice, and the interstices be filled with a strong acetic acid, which may be collected by draining. The radical vinegar of the apothecaries, made by dissolving in it a little camphor, or fragrant essential oil, has a specific gravity of about 1.070, and consists of one part of water to two of the crystallized acid. The pungent smelling salt is made by moistening the sulphate of potash with a little concentrated acetic acid. Acetic acid acts upon iron, zinc, copper, and nickel, in the metallic state, and upon the oxides of various other metals; its combination with the latter being usually effected by mixing a solution of their sulphates, with that of an acetate of lead. It has a very slight action upon metallic tin, when highly concentrated. The strongest acetic acid will, we are informed, dissolve metallic lead, which is contrary to the statements of chemical authors. Acetic acid dissolves resins, gum-resins, camphor, and essential oils. Its odour is employed in medicine to relieve nervous headache, fainting, and sickness from crowded rooms. Its anti-contagious powers are not now so confidently relied upon as formerly. It is extensively used in calico printing. It unites with all the alkalies, and most of the earths,

and with these bases it forms compounds, some of which are crystallizable, and others have not yet been reduced to a regularity of figure. For the properties and uses of these combinations we refer the reader to Dr. Ure's *Dictionary of Chemistry*.

ACID, MURIATIC, may be obtained by distillation from a mixture of common salt with clay or bole, which is the original process; but it is now only used where fuel and pottery earths are cheap, and oil of vitriol dear. The method most commonly practised at present to obtain it, is to decompose the muriate of soda, or common salt, by sulphuric acid, and condensing the muriatic acid gas in water, for which it has a great affinity. The annexed engravings represent the most approved apparatus for this purpose.

Fig. 1.

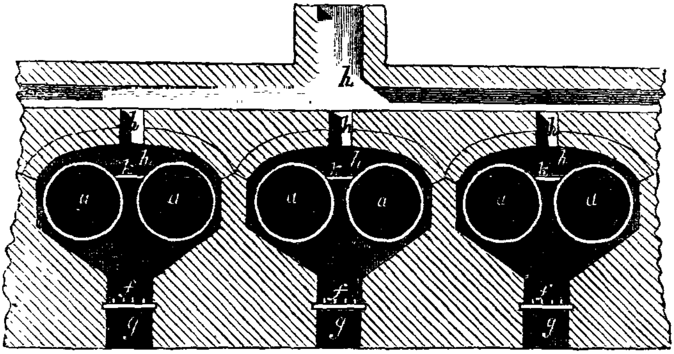


Fig. 2.

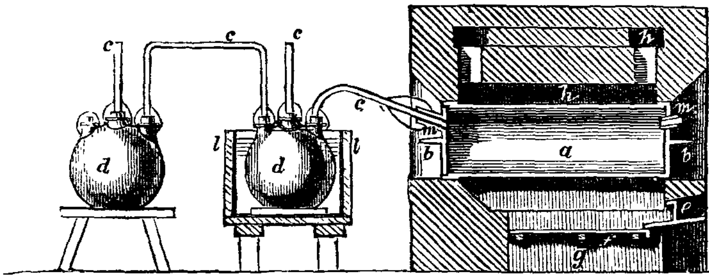


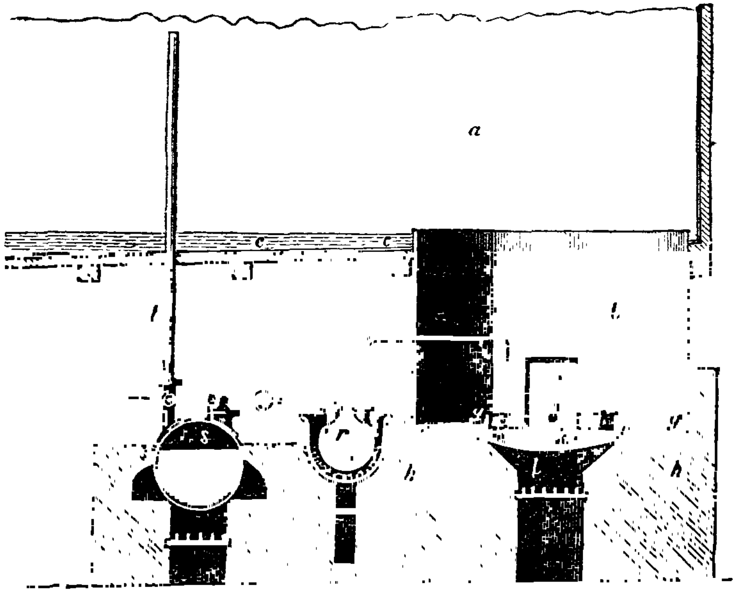
Fig. 1 is a transverse, and *Fig.* 2 a longitudinal section of a bench of cast-iron retorts *a*, (generally twenty in number,) resembling those used in gas works. They are placed in pairs, each pair having a separate fire-place *e*, grate *f*, and ash-pit *g*. Every part of the cylinder should be equally heated, that the decomposition of the salt may be simultaneous, and the iron be as little as possible injured by the acid. For this purpose, a plate of cast-iron *k*, is placed between the cylinders; and the flues *h* are constructed so as to produce an equal draught throughout every part of the furnace. The cylinders are closed at each end by a plate of cast-iron luted into the rim of the cylinder. Each end plate has a handle *b*, of cast-iron, and a small tube *m*, projecting from the upper part of the plate, for the purpose at one end of pouring in the sulphuric acid, and of conveying away the products at the other. The first cylinder communicates by the bent glass pipe *c*, with the earthen vessel *d*, which has three mouths, and which again communicates by two other bent tubes *c*, with two similar vessels. All the gas not condensed in the first bottle *d*, passes into the other bottle *d*; at the same time the second bottle *d* receives the gas from the second cylinder, and transmits the gas which it does not condense to a third bottle, and so on to the last bottle, which receives the gas not condensed in all the others, as also the

gas from the last cylinder. From this bottle whatever gas is not condensed, is transmitted through a second range of bottles half filled with water, which will absorb two-fifths of its weight of muriatic acid; and in this second range the whole of the gas is condensed. The first range, it should be observed, is placed in a trough *l*, through which is maintained a current of cold water. The purest acid is obtained in the second range of bottles; that which is condensed in the first range containing always a little sulphuric acid, and sometimes sulphate of soda and muriate of iron. Each cylinder is charged with about 160lbs. of common salt, and the end is luted with clay, and the fire is kindled; 128lbs. of sulphuric acid at 66°, Baumé's areometer, are then poured on the salt. After the gas ceases to come over, the end plate is taken off, the sulphate of soda removed, and the operation repeated: thus 130lbs. of muriatic acid, of the spec. grav. 1.190, may be obtained from 100lbs. of salt. Muriatic acid, mixed with nitric acid, forms aqua regia, which is a solvent for gold and platinum: it is also used to prepare muriate of tin for dyers, to scour metals, and numerous other purposes.

ACID, Nitric, may be made in various ways, but that most commonly employed, is to decompose saltpetre, or nitrate of potash, by concentrated sulphuric acid, in an apparatus similar to that used in the preparation of muriatic acid, except that four cylinders are usually heated by one fire. The cylinders communicate by tubes with three or four rows of earthen vessels, the two first of which are plunged in water. The tubes which proceed from the cylinders must be of glass, that the colour of the gas which passes may be seen, as it shews the progress of the operation; the other tubes may be of earthenware. Each cylinder is charged with 170lbs. of nitrate of potash, and 100lbs. of sulphuric acid, of 1.845 spec. grav. The heat must be equally applied, and the fire conducted slowly. As the operation advances, the vapours become red; and it is finished when these vapours are no longer visible: a brisk fire is made towards the close to disengage all the gas. The acid condensed in the first row of bottles is always the least pure: that contained in the second range and in part of the third contains only nitrous acid; this is disengaged by carrying it to ebullition in glass retorts; the ebullition is gradually stopped when it becomes white, and it is in this state sold in commerce. All the weak acid in the last vessels is again put into the first or second range instead of pure water, and water is always put in the last row to complete the condensation. The acid thus obtained is not sufficiently pure for all purposes for which it is wanted, but requires to be distilled in glass retorts, taking care to separate the products. The first portions which are volatilized are chlorine and nitrous acid; these are separated when the liquor in the retorts becomes white, after which the pure nitric acid comes over. The distillation should be stopped when nine-tenths of the acid in the retort is volatilized. Nitric acid is employed in the manufacture of sulphuric, oxalic, and other acids, in the composition of *aqua regia*, in making the red precipitate, in dying, gilding, assaying money, in parting gold, and numerous other processes.

ACID, Sulphuric, is obtained either by simple distillation from copperas, (which was the original method,) or by the combustion of sulphur, in large leaden chambers, in combination with substances yielding a large supply of oxygen, which is the method generally practised at the present day. The latter process is conducted in various ways; the most usual method in this country is the following. Common brimstone, coarsely ground, is mixed with saltpetre, in the proportion of 8 lbs. of the former to 1 lb. of the latter; the mixture is spread upon iron plates set upon stands of lead, in a large chamber, lined with lead, and covered at the bottom with a thin sheet of water. The materials are ignited by means of a hot iron, and the door is closed. The sulphur in vapour then combining with the oxygen of the nitre, forms sulphuric acid, and condenses in the water, which is afterwards drawn off and concentrated, first in leaden vessels, and then in glass retorts, (which are sometimes lined internally with platinum); but some manufacturers dispense with the leaden boilers altogether. In some of the more recently established manufactories in France, the following process has been employed with very advantageous results:—The sulphur is burned upon an iron plate, set over a furnace, beneath a leaden cylinder, opening into a

leaden chamber, containing about 20,000 cubic feet: at the same time, a retort placed in a sand bath, and containing $9\frac{3}{4}$ lbs. of nitric acid, and $1\frac{1}{4}$ lb. of molasses, is heated, the nitrous gas disengaged being conducted into the leaden cylinder about 2 feet above the burning sulphur, and this operation being continued until all the nitrous gas is disengaged. From the residue in the retort oxalic acid is obtained. About two hours after the combustion has commenced, steam is admitted into the chamber by a pipe, which enters about the middle of the chamber. Soon after the introduction of the steam, a condensation is perceived in the chamber, and a small hole is opened to admit a supply of atmospheric air. When the condensation is completed, which is commonly in about three hours' time from the commencement of the operation, a door in the cylinder, and two valves placed under a tall chimney, are opened, in order to renew the air in the chamber, after which the operation may be repeated. The bottom of the chamber should always be covered with liquid, and it is inclined to the horizon, so that the liquid may be 9 inches deep at one end, and only $1\frac{1}{2}$ at the other, and only the overplus is drawn off daily. The acid may be concentrated in the chambers to about 1.450 spec. grav.; after which it is removed to leaden boilers, and brought to a spec. grav. of 1.600; the remaining requisite concentration is effected in glass and platinum retorts. A quantity of acid comes over during the evaporation, which is condensed by a leaden worm fixed to the neck of the retort. The annexed cut represents the apparatus employed in this process.



a is a portion of the chamber lined with lead; *b*, the leaden cylinder entering the chamber at one end of it, and rising about 10 inches above the floor *c*. The cylinder at its lower part *d*, turns inwards and upwards, forming a gutter *e*, concentric with the cylinder; in this gutter a portion of weak acid is always kept up as high as the line *g*, to prevent the lead from getting too much heated. The whole is placed on a mass of brick-work *h*, in the middle of which there is an iron dish *k*, having a convex bottom, and a rim 3 inches high; it is mounted over a furnace *l*. *m* is a door in the leaden cylinder, and *n*, an air-hole in the door, fitted with a stopper; *r*, a glass mattress, containing the nitric acid and molasses; *s*, the steam boiler; *t*, the steam pipe. Sulphuric acid is very extentively used in the chemical arts, particularly in bleaching, and some of the processes

of dying; in the manufacture of the nitric and muriatic acids, and in numerous other branches of manufacture. The combinations of this acid with various bases, are called sulphates, many of which are of great utility in medicine and the arts. The acidulous sulphate of alumina, combined with potash or ammonia, forms the important article called ALUM, which see.

ACRE. A measure of land, amounting to 4 square roods, or 160 square poles or perches. The English statute acre is about 3 roods and 6 falls standard measure of Scotland. The Welsh acre contains commonly 2 English ones. The Irish acre is equal to 1 acre 2 roods and $19\frac{27}{121}$ perches English. The number of acres in England, according to Dr. Grew, amounts to 46,080,000.

ADAMANT. The ancient name of the diamond. This term is also sometimes applied to the scoriæ of gold, and to a species of iron ore.

ADAMANTINE SPAR. There are two varieties of this important mineral known in Europe, one of which is brought from China, the other from India. They are both remarkable for their extreme hardness, which approaches to that of the diamond, and is therefore used in polishing gems and steel. In India, corundum powder is formed into a paste with lac resin, and moulded into grindstones of a very durable nature.

ADHESION denotes an union, to a certain degree, between two distinct substances, and differs from *cohesion,* (with which the former word is often confounded,) inasmuch, as the latter term is alone properly applicable to the retaining together of the component particles of the same mass. Adhesion is, however, of two kinds; the one, a species of natural attraction, which takes place between the surfaces of bodies, whether similar or dissimilar, and which, in a certain degree, connects them together; the other, the joining or fastening together of two or more bodies, by the application of external force. With respect to the first-mentioned, it has been proved, that the power of adhesion is proportionate to the number of touching points; and this, in solid bodies, depends upon the degree in which their surfaces are polished and compressed. The effects of this power are extremely curious, and in many instances astonishing. It is stated by Musschenbroëk, that two cylinders of glass, of rather less than 2 inches diameter, being heated to the temperature of boiling water, and brought into contact with melted tallow between their surfaces, required a force of 130 pounds to separate them; pieces of lead, of the same area of surface, required 275 pounds; and soft iron, 300 pounds. The experiments made and described by Mr. Martin, in the *Philosophia Britannica,* make the force of this kind of adhesion much greater than Musschenbroëk. He took two leaden balls, and having carefully scraped off, with the edge of a sharp pen-knife, so much of their spherical surfaces as to form two planes of one-thirtieth of an inch in area, he pressed them together forcibly, and with a gentle turn of the hand. The adhesion of these small surfaces was such, that he lifted, with the balls so united, above 150 pounds weight. The adhesion between two brass planes $4\frac{1}{4}$ inches in diameter, with grease smeared over their surfaces, was such, that he could never meet with two men strong enough to separate them by pulling against each other. The editor of this work had put into his hand many years ago, two brass plates, of about 2 inches diameter, having their surfaces so perfectly flat, that, without any interposing matter, he could only separate them by sliding them edgeways. With respect to the second-mentioned kind of adhesion, some useful experiments were made by Mr. B. Bevan, on the adhesive force of iron nails, screws, and pins; also of the common cements, glue, and sealing-wax, which that gentleman communicated to the editor of the *London Mechanics' Magazine.* The following is a condensed account of them :—

ADHESION OF IRON NAILS, in which Mr. Bevan's object was to determine, *first,* the adhesive force of different kinds of nails, when driven into wood of different species : *second,* the actual weight, without impulse, necessary to force a nail a given depth : *third,* the force requisite to extract a nail when so driven. Mr. Bevan observes, that the theoretical investigation points out an inequality of resistance to the entrance and extraction of a nail, supposing the thickness to be invariable; but as the general shape of nails is tapering towards their points, the resistance of entrance necessarily becomes greater than that of

extraction; in some experiments he found the ratio to be about 6 to 5. The following Table exhibits the relative adhesion of nails of various kinds when driven into dry Christiana deal, at right angles to the grain of the wood.

Description of Nails used.	Number to the lb. avoirdupois.	Inches long.	Inches forced into the wood.	Pounds required to extract.
Fine sprigs	4560	0.44	0.40	22
Ditto	3200	0.53	0.44	37
Threepenny brads	618	1.25	0.50	58
Cast-iron nails	380	1.00	0.50	72
Sixpenny nails	73	2.50	1.00	187
Ditto	..	..	1.50	327
Ditto	..	..	2.00	530
Fivepenny nails	139	2.00	1.50	320

The percussive force required to drive the common sixpenny nail to the depth of 1½ inch into *dry Christiana deal*, with a cast-iron weight of 6.275 lbs. was four blows or strokes falling freely the space of 12 inches; and the steady pressure to produce the same effect, was 400 lbs. A sixpenny nail driven into *dry elm*, to the depth of one inch across the grain, required a pressure of 327 lbs. to extract it; and the same nail driven end-ways or longitudinally into the same wood, was extracted with a force of 257 lbs. The same nail driven 2 inches end-ways into *dry Christiana deal*, was drawn by a force of 257 lbs.; and to draw out 1 inch, under like circumstances, took 87 lbs. only. The relative adhesion, therefore, in the same wood, when driven transversely and longitudinally, is 100 to 78, or about 4 to 3 in dry elm, and 100 to 46, or about 2 to 1 in deal; and in like circumstances, the relative adhesion to elm and deal is as 2 or 3 to 1. The progressive depths of a sixpenny nail into dry Christiana deal, by simple pressure, were as follows:—

One quarter of an inch, a pressure of	24 lbs.
Half an inch	76 —
One inch	235 —
One inch and a-half	400 —
Two inches	610 —

In the above experiments, great care was taken by Mr. Bevan to apply the weights steadily, and towards the conclusion of each experiment, the additions did not exceed 10 lbs. at one time, with a moderate interval between, generally about one minute, sometimes ten or twenty minutes. In other species of wood, the requisite force to extract the nail was different. Thus, to extract a common sixpenny nail, from a depth of one inch, out of

Dry oak, required	507 lbs.
Dry beech	667 —
Green sycamore	312 —

From these experiments, we may infer that a common sixpenny nail driven two inches into dry oak, would require a force of more than half a ton to extract it by a steady force.

Adhesion of Iron Pins. The force necessary to break or tear out a half-inch iron pin, applied in the manner of a pin to a tenon in the mortice, has likewise obtained the attention of the same celebrated experimentalist. The thickness of the board was 0.87 inch, and the distance of the centre of the hole from the end of the board, 1.05 inch. The force required was 976 lbs. As the strength of a tenon from the pin-hole may be considered in proportion to the distance from the end, and also as the thickness, we may, for this species of wood, obtain the breaking force in pounds nearly, by multiplying together one thousand times the distance of the hole from the end, by the thickness of the tenon in inches.

Adhesion of Glue. Mr. Bevan glued together by the ends, two cylinder, of dry ash wood, one-fifth of an inch in diameter, and about 8 inches long

After they had been glued together twenty-four hours, they required a force of 1260 lbs. to separate them; and as the area of the circular ends of the cylinders were 1.76 inch, it follows that the force of 715 lbs. would be required to separate one square inch. It is proper to observe, that the glue used in this experiment was newly made, and the season very dry; for in some former experiments on this substance, made in the winter season, and upon some glue which had been frequently made, with occasional additions of glue and water, he obtained a result of 350 to 500 lbs. to the square inch. The present experiment was, however, conducted upon a larger scale, and with care in the direction of the resultant force, so that it might be, as near as practicable, in a line passing at right angles through the centre of the surfaces in contact. The pressure was gradually applied, and was sustained two or three minutes before the separation took place. Upon examining the separated surfaces, the glue appeared to be very thin, and did not entirely cover the wood, so that the actual adhesion of glue must be something greater than 715 lbs. to the square inch. Upon comparing with this, the natural *cohesive* force laterally of wood of the same kind, Mr. Bevan found it to be only 562 lbs.: consequently, if two pieces of this wood were well glued together, the wood would have yielded in its substance before the glue. From a subsequent experiment made on solid glue, the cohesive force was found to be 4,000 lbs. per square inch; from which it may be inferred, that the application of this substance as a cement is susceptible of improvement.

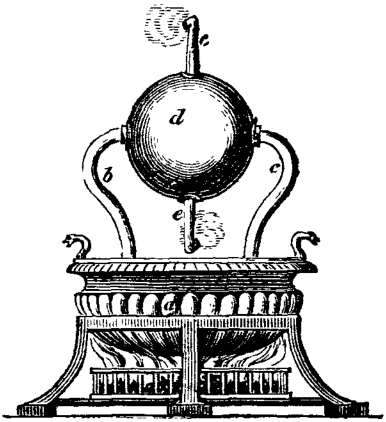
Adhesion of Sealing Wax. The best red sealing wax was proved to have a cohesive force equal to 1500 lbs. per square inch, and the black sealing wax was rather more than 1,000 lbs. to the square inch; the deficiency in the latter. we suppose, was owing to the diminished quantity of lac resin used in the composition.

ADIT, in Mining, is a subterraneous passage, slightly inclined, about 6 feet high, and 2 or 3 feet wide, begun at the bottom of a neighbouring valley, and continued up to the vein, for the purpose of carrying out the minerals and drawing off the water.

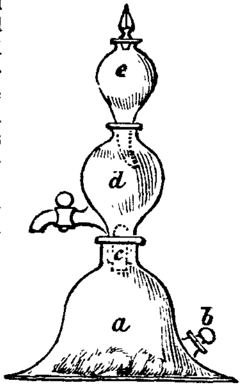
ÆOLIAN HARP, or harp of Æolus, is a musical instrument, which probably received its name from the effects produced upon it by the air without human aid. It consists of a slight box of fibrous wood, usually deal, containing a low bridge at each end, over which is stretched, upon pegs, a series of fine cat-gut strings, generally about fifteen in number, which being of equal size and length, are therefore unisons. Its length should correspond with the size of the window or other aperture where it may be placed; its width need not be more than from 4 to 6 inches, and in depth from 3 to 4 inches It should be placed between the lower sash and sill of a window, with its strings uppermost, under which is a circular opening, as in the belly of the guitar. When the wind blows athwart the strings, it produces the effect of a choir of music in the air, swelling or diminishing its sounds according to the strength or weakness of the blast. Mr. Crossthwaite has simplified this instrument by dispensing with the sounding-board, and making it simply of two deal boards, with the strings extended between them. Father Kircher being the first European author who described it, the invention has been attributed to him; but the learned Mr. Richardson, in his *Dissertation on the Languages and Manners of the East*, says, that an instrument of the kind had been long in use in the East, before the time of Kircher.

ÆOLIPILE. A name that has been given to an instrument variously modified, for converting in a close vessel water into steam. The first individual who used it, appears to have been Hero the elder, a Grecian mechanic, who settled in Alexandria about 130 years prior to the christian era, whose ingenuity and talents being fostered by the Egyptian monarch, was the probable cause of his interesting discoveries being handed down to us in his work entitled *Spiritalia, or Pneumatica*. Although in the state that he has presented it to us in his æolipile, it cannot be regarded as one of his most useful inventions, (his fountain for raising water by compressed air possessing far more intrinsic merit,) still as being the earliest germ of that great mechanic power which seems destined to change the face of the entire civilized world, it is well deserving of

a description in this place, which we shall give, with reference to the subjoined figure. Over a small furnace was placed a vase or caldron *a*, containing water, from the cover of which proceeded two arms *b c*, forming the axis of a hollow globe *d*. The arm *b*, is a steam pipe, the other arm *c*, is solid, having its extremity formed into a conical pivot. At right angles to the axis of the hollow globe, there proceeds from it two tubes *e e*, bent at their extremities, which form the outlets of the steam. Heat being applied to the caldron, raises the steam, which flowing through the tubular axis *b*, enters the globe; thence the steam finds its way through the tubes *e e* into the atmosphere, the reaction of the latter producing a rotatory motion of the globe, the velocity of which will depend upon the strength of the steam.

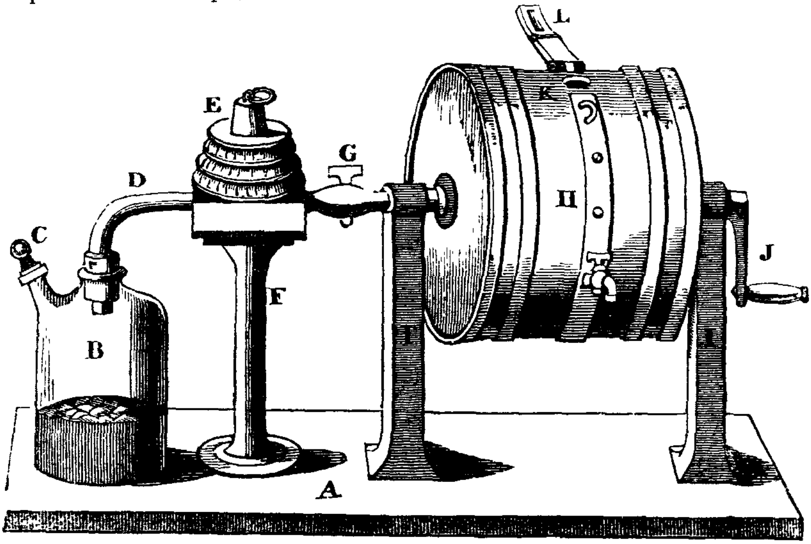


AERATED WATERS. This term being popularly applied to a variety of acidulous and alkaline beverages more or less impregnated with fixed air, or carbonic acid gas, we introduce our article on the subject in this place; and as the manufacture of these liquids has of late years become of considerable extent, owing to their agreeable as well as medicinal properties, we purpose describing several ingenious apparatuses that have been used, or are still employed, for the purpose. Water absorbs under the natural pressure of the atmosphere about its own bulk or volume of carbonic acid gas. If a pressure be applied equal to two atmospheres, the water will absorb double its own volume, its absorbing power increasing as the pressure. Water thus impregnated acquires a pleasant acid taste, to which is usually added a small quantity of potash or soda, and such flavouring or other ingredients as may be required to imitate the natural mineral waters. *Nooth's apparatus* was one of the earliest contrivances, and is adapted to the preparation of small quantities of aerated water. It is represented in the subjoined cut, and consists of three vessels; the lowest *a*, is flat and broad, so as to form a good basis; in this is put a quantity of chalk or pounded marble, and some dilute muriatic or other acid is introduced through a screwed stopper *b*. The gas being thus generated, passes through the tube *c*, in which a glass valve opens upwards into *d*, which contains the water or solution to be impregnated, and is provided with a stop-cock to draw off the liquid. The tube of the uppermost vessel *e*, dips into *d*, occasioning therein some pressure; and the gas which is not absorbed in the latter, passes up into *e*, which being provided with a heavy stopper, acts as a valve, and causes a considerable pressure of the gas upon the water within it. The gas which is not absorbed by the water in *c* or *d*, escapes by the aperture at top. Another apparatus of great simplicity, and adapted to operating upon a more extended scale, is delineated in the subjoined cut.



A is a strong plank on which the vessels are fixed; B is a bottle, containing a quantity of pulverised carbonate of lime or chalk; C is the tubulure and stopper of the bottle; D a bent tube for conveying the gas into the bellows E, which are supported by the upright stand F; G is a stop-cock connected with the tube D, which passes from thence into the strong iron-hooped air-tight barrel H, suspended by its axis on the upright

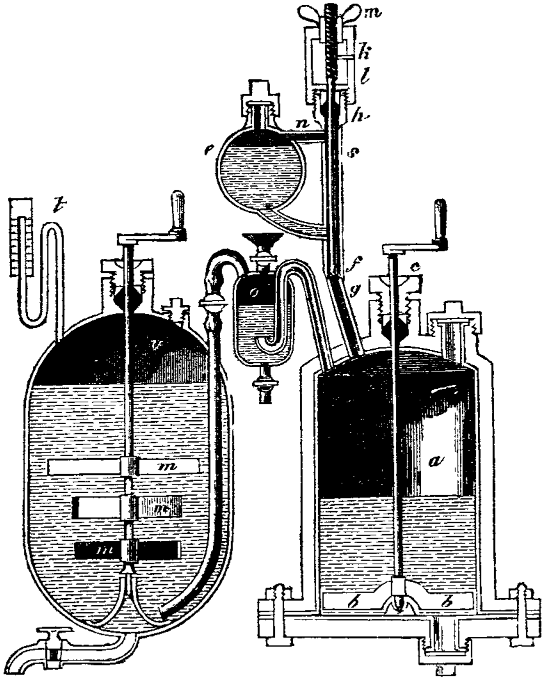
pillars I I. In using this apparatus, the cask is to be half filled with distilled or spring water; the hole K is then to be stopped air-tight with a good bung, which is to be fastened down by means of the jointed strap or hasp L, being passed over the staple, and secured by a bolt or key put through the same.



Then pour through the tubulure of the bottle some sulphuric acid, diluted with five or six times its weight of water, over the chalk, and close the aperture by the screw-stopper C. Having taken off the weight from the bellows, the carbonic acid extricated from the chalk by the action of the acid, passes out of the bottle into the bellows, through the tube D, which has an orifice opening under them. When the bellows are fully distended, the cock G is to be turned, and the weight being placed upon the bellows, the gas is thereby pressed downwards into the barrel, and is there absorbed by the water, which is accelerated by giving the barrel a few quick turns by the winch J. The contents of the barrel may then be drawn off into stone bottles, which should be quickly corked, and bound down with copper wire, to be preserved for use.

A very complete machine, invented by Mr. Cameron, of Glasgow, calculated to offer a strong resistance to the pressure of the gas, and force a considerable quantity into water, is shown on the next page. The gas generator *a*, is made of cast iron, three quarters of an inch thick, and lined interiorly with sheet lead, (of 9 lbs. weight to the foot,) to prevent the action of the acid upon the iron. This vessel contains about 15 gallons, and is filled up to the dotted line by a mixture of whiting and water; it has an agitator *b*, also lined with sheet lead, and which works on a pivot at the bottom, the axis passing through the stuffing-box *c*, at the top of the vessel. The acid-holder *e*, is formed of lead, of the capacity of two gallons, and is filled with oil of vitriol up to the dotted line. The acid is kept from running down into the generator by means of the conical plug *f*, which fits into a conical opening in the leaden pipe *g*. This plug is attached to a rod, and moves up and down through the stuffing-box *h*, and is prevented from turning round by means of a pin *k*, moving in a slit in the bridle *l*, and the screw-nut *m*, is rivetted loose into the top of the bridle. The pipe *n*, which forms a communication between the top of the acid-holder *e*, and the pipe *s*, in which the plug-rod moves, preserves an equilibrium of pressure, so as to prevent the acid from rising higher in the pipe *s* than the level of the acid in the acid-holder, by which means the brass work of the stuffing-box is preserved from injury. To prevent any of the sulphuric acid from being carried over by the effervescence

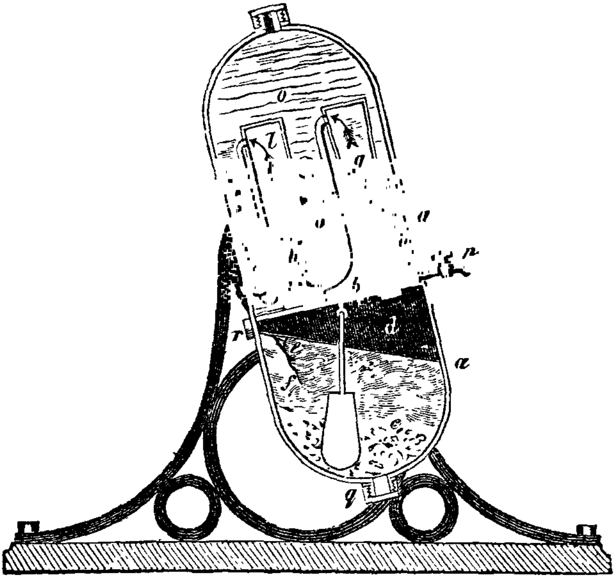
an intermediate vessel *o*, containing about three gallons, is formed either of thick sheet lead alone, or of cast iron, lined with lead. This intermediate vessel is filled with water up to the dotted line. The impregnator *v* should contain about 16 gallons. It may be made either of copper tinned, or of cast iron,



lined with sheet-lead; and the agitator *m* may either be of tinned copper, or of maple-wood; which last, giving no taste to the water, is for that reason preferable. This impregnator is filled up to the dotted line with water, to which, in making saline waters, the proper proportion of sesqui-carbonate of soda, carbonate of magnesia, or other ingredient, is to be added. A pressure-guage *t*, of quicksilver, is to be placed at a little distance, and connected by means of a leaden pipe. The operation of this apparatus is very simple. By turning the nut *m* the plug is raised, allowing the sulphuric acid to run down into the generator *a*, where it acts upon the whiting, disengaging the carbonic acid gas in proportion to the quantity of sulphuric acid admitted at a time. The nut *m* being turned the other way, lowers the plug, and stops the descent of the sulphuric acid, thus regulating the disengagement of the gas, and preventing too violent an effervescence. The disengaged gas passes through the intermediate vessel into the impregnator *v*, where it is absorbed by the water. The impregnated water is then drawn off into strong half-pint bottles, by means of a cock, which descends to the bottom of the bottle; on withdrawing the bottle, it should be instantly corked, and the corks be wired or tied down.

A patent has just been granted to Mr. F. C. Bakewell, of Hampstead, for a very compact and ingenious apparatus for the preparation of aerated waters, the peculiarity of which consists in the gas generating and the gas impregnating apparatus being inclosed in the same vessel, and in the whole operation being effected by a simple oscillating motion. A correct idea of this machine may be formed by the annexed figure, (representing a vertical section of its principal parts,) together with the subjoined explanation. *a a* exhibits an external casing of

a cylindrical form, with spherical ends, made strong enough to resist a pressure of several atmospheres; *b* is a partition, about two-thirds from the top of the vessel, separating it into two parts. The bottom part *c* is a receptacle for the chalk, or other suitable material, mixed into a pasty consistency with water; *d* is



a vessel containing dilute muriatic or sulphuric acid, which is made to pass out in small quantities, as required, at the aperture *e* into the vessel *c; f* is a guard to prevent the aperture *e* from being choked up; *g* is a pipe, of the form of a truncated cone inverted, being about an inch diameter at bottom, and two inches at the top. This pipe is fitted into an aperture in the partition *b*, and is closed at the upper end; its object is for the ascent of the gas as it is generated, which passes from the top down an external pipe, into the lower part *i* of a vessel *k*, and through a small aperture the tenth of an inch diameter, (or through several apertures whose total areas do not exceed the tenth of an inch,) through the partition into the upper part of the vessel *h*. This vessel, which is denominated the washing vessel, is furnished with two shelves, sloping in opposite directions near its top, to detain the gas longer in its passage through the aperture *l* to an external pipe, furnished with a perforated rose, for distributing the gas as it escapes into the water to be impregnated, contained in the vessels *o o; p* is a stop-cock for drawing off the impregnated water as required; *q* is an aperture for the introduction of the chalk and water; *r*, another for the introduction of the acid; and *s*, another for the water to be aerated: each of these apertures is provided with a screwed cap, to stop them securely after the respective vessels have been charged. The apparatus is made to swing on two pivots, one of which is shown in section at *t*. When the chalk and acid receptacles are to be supplied with those ingredients, the apparatus is to be turned on its pivots to a horizontal position, with the aperture *r* upwards, and a funnel or hopper, with a bent stem, is to be employed in filling the vessel *c c; n* is an end view of a pendulum or agitator, of the form of an arch of a circle, extending across the bottom of the vessel, and suspended at its two extremities; one of the suspension wires is shown in the drawing. The apparatus having been charged as above described, is to be put into vibration on its pivots, by which the chalk and water will be effectively agitated by the motion of the pendulum, while a

small portion of acid will escape from the vessel *d*, into the vessel *e*, to keep up the generation of the gas as it passes off to the water in *a*, which will, at the same time, by the vibration of the apparatus, be thoroughly mixed with the gas as it escapes through the rose *n*. An elegant apparatus, adapted for saturating liquids with the carbonic acid, as well as other gases, was invented by M. Clement, for which, see the article ABSORBING AND PRODUCTIVE CASCADE. Some manufacturers of aerated waters employ mechanical means to force the gas into the water, by the use of a transferring pump or syringe, which is connected at one end with a bladder, or other reservoir of the gas, and at the other, with a vessel, or single bottle of water; the up-stroke of the pump extracting the gas from the bladder, and the down-stroke transferring it into the water.

AERIAL ACID. See CARBONIC ACID.

AERIFORM FLUIDS. A name frequently given to the gases.

AEROGRAPHY. AEROLOGY. AEROMETRY. These three terms have been indifferently applied to that science which treats of the limits, dimensions, pressure, elasticity, rarefaction, condensation, and other properties of our atmosphere; but these terms are generally disused by modern writers on this branch of natural philosophy, by whom it is now designated PNEUMATICS, which see. See also AIR, ATMOSPHERIC.

AEROMETER. An instrument, to which this name has been given by the inventor, Dr. M. Hall, for making the necessary corrections in pneumatic experiments to ascertain the mean bulk of the gases. It consists of a bulb of glass, of 4½ cubic inches capacity, blown at the end of a long tube, whose capacity is 1 cubic inch. This tube is inserted into another tube of nearly equal length, which is supported on a sole; and the first tube is sustained at any required height within the second, by the pressure of a spring. Five cubic inches of atmospheric air, at a medium pressure and temperature, are to be introduced into the bulb and tube, of the latter of which it will occupy one-half. The other half of this tube, and part of the tube in which it is inserted, are to be occupied by the fluid of the pneumatic trough, whether water or mercury. The point of the tube at which the air and fluid meet, is to be marked by the figure 5, to denote 5 cubic inches. The upper and lower halves of the tubes are each divided into five parts, representing tenths of a cubic inch. The external tube has a scale of inches attached.

AEROSTATION. The art of navigating the air in aerostatic machines. See BALLOONS.

AERUGO. The rust or oxide of metal, particularly that on copper, called verdigris. Thus, in the *Pharmacopeia Londinensis*, prepared verdigris is termed *Aerugu præparata*.

AETHER. An extremely thin, subtle, penetrating fluid, much finer than air, which has been considered by the ancient and many modern philosophers to be diffused throughout the universe, but in its pure state to commence beyond the limits of our atmosphere. The existence of such a fluid is wholly hypothetical; yet it has given birth to conjectures as indefinite as the space which has been assigned for its circulation. With some of the ancient philosophers it was considered the origin of all things; an attenuation of fire; to be immortal; knowing all things; seeing, hearing, and determining whatsoever is, or shall be hereafter. From this fluid, existing only in perfection in the highest heavens, all grosser elements were first derived, and, from these, the various productions of nature. Here the gods were enthroned, and the stars rolled in sublime harmony around them! Although the poets went hand in hand with the philosophers in this speculation of science, it would long since have been exploded from all connexion with the inductive philosophy, but for the sanction that has been given to it by some conjectures of Sir Isaac Newton.

AETITES, or EAGLE-STONES; so called, from a popular notion that eagles took them up into their nests to preserve their eggs from decay. They are crustated hollow stones, containing a nucleus, which rattles on being shaken; they usually consist of oxide of iron, mixed with silex and alumina.

ÆTNA SALT. The impure sal ammoniac found in the crevices of Ætna and other volcanoes, and on the surfaces of the lava.

Æ. (For many other words which were formerly commenced with this diphthong, see the letter E.)

AFFINITY, CHEMICAL. See ATTRACTION.

AGARIC, MINERAL, or MOUNTAIN MEAL, found in the clefts of rocks, and on the roofs of caves, is a native carbonate of lime. It is used medicinally in dysenteries and other disorders. N. Fabroni describes it as a stone of loose consistence, abundant in Tuscany, of which bricks may be made either alone, or with the admixture of one twentieth part of clay, so light as to float in water.

AGATE. A mineral whose basis is calcedony, blended with variable proportions of jasper, amethyst, quartz, opal, heliotrope, and carnelian. *Ribbon agate* consists of alternate and parallel layers of calcedony with jasper, or quartz, or amethyst. The most beautiful comes from Liberia and Saxony; it occurs in porphyry and gneiss. *Brecciated agate* is of Saxon origin; it has a base of amethyst, containing fragments of ribbon agate, constituting the beautiful variety. *Fortification agate*, found in Scotland and on the Rhine, is in nodules of various shapes, imbedded in amygdaloid. On cutting it across, and polishing it, the interior zig-zag parallel lines bear a considerable resemblance to the plan of a modern fortification. In the very centre, quartz and amethyst are seen in a splintery mass, surrounded by the jasper and calcedony. *Mocha stone*, from Mocha, in Arabia, where it is chiefly found, is translucent calcedony, containing dark outlines of arborization, like vegetable filaments. *Moss agate*, so called from its ramifications of a vegetable form, is a calcedony, variously coloured, and occasionally traversed with irregular veins of red jasper. An onyx agate set in a ring belonging to the earl of Powis, contains the chrysalis of a moth. Agate is found in most countries, chiefly in trap rocks and serpentine. The *oriental agate* is almost transparent, and of a vitreous appearance. The *occidental* is of various colours, and often veined with quartz or jasper. Agates are most prized when the internal figure nearly resembles some animal or plant. Agates are artificially coloured by immersion in metallic solutions. They are extensively used in Paris for making cups, rings, seals, handles for knives and forks, sword hilts, beads, smelling bottles, snuff boxes, &c. At Oberstein, on the Rhine, where the stones are abundant, they are cut and polished on a considerable scale, and at a very moderate price. The surface to be polished is first coarsely ground by large millstones of a hard reddish sand-stone, moved by water. The polish is afterwards given on a wheel of soft wood, moistened and imbued with a fine powder of hard red tripoli, found in the neighbourhood. Antiquaries use the term agate to denote a stone of the kind engraved by art. In this sense agates make a species of antique gems, in the workmanship of which we find eminent proofs of the great skill and dexterity of the sculptor. Several agates of exquisite beauty are preserved in the cabinets of the curious.

AGENT, in a general sense, denotes any active power or cause. In natural philosophy, the term is applied to such bodies as have a power to act upon other bodies in a certain and determinate manner.

AGGREGATE, in a general sense, is the sum of several things added together. In chemistry, the united mass is called an aggregate, when it does not differ in its chemical properties from the bodies of which it was originally composed. Elementary writers call the smallest parts into which an aggregate can be divided, without destroying its chemical properties, integrant parts. Thus we may conceive the integrant parts of common salt to be the smallest parts which can remain without change; and beyond these, that any further subdivision cannot be made without developing the component parts, the alkali and the acid; and that the division of the latter must resolve them into their constituent principles.

AGITATION. In general, the act of shaking a body, or tossing it about.

AGITATORS. Instruments used in various processes for the purpose of agitation. See BREWING, DISTILLATION, EVAPORATION, &c.

AGRICULTURAL IMPLEMENTS. See, under the respective heads, PLOUGH, HARROW, &c.

AGRICULTURE is the art of cultivating the earth, so as to preserve or increase the natural fertility of the soil, as well as to render sterile tracts productive of vegetation useful to man; and the perfection of this art may be said to consist in obtaining the greatest quantity of the required product, from a given quantity of land, at the least possible expense of labour and material. Besides the production of grain and leguminous plants, which usually forms the chief business of the farmer, agriculture includes the culture of trees, and every description of plants; their planting, pruning, grafting, &c.; hence horticulture, or gardening, is a branch of this art. It includes also the breeding and management of cattle, since their manure and their labour are essential to the business of husbandry. Nothing would tend more to the successful practice of this the most important of all arts, than the study of chemistry by the farmers. If a soil be unproductive, it must be owing to some defect in its constitution, which may not be apparent even to the eye of the most experienced husbandman. Not all his observation, nor all his practice, without the aid of chemical knowledge, will afford him any means either of ascertaining the cause, or removing the effect. By chemical analysis, however, the cause is readily determined, and the remedy made obvious. If the *salts of iron* be present, they may be decomposed by lime; if an excess of silicious sand, the application of clay and calcareous matter will improv [illegible] be in excess, liming, or paring and burning, will be [illegible] ent rules laid down by Sir Humphrey Davy, in his [illegible] particularly deserving of attention. In cases wher [illegible] with a view to its improvement, it ought, in all cases, if possible, to be compared with an extremely fertile soil in the neighbourhood, and in a similar situation. The difference given by their analyses would indicate the methods of cultivation, and thus the plan of improvement would be founded upon accurate scientific principles. If the fertile soil contained a large quantity of sand in proportion to the barren soil, the process of melioration would depend simply upon a supply of this substance; and the method would be equally simple with regard to soils deficient in clay or calcareous matter. In the application of clay, sand, loam, marl, or chalk, to lands, there are no particular chemical principles to be observed; but when quick-lime is used, great care must be taken that it is not obtained from the magnesian limestone, for in this case, as has been shewn by Mr. Tennant, it is exceedingly injurious to land. The magnesian limestone may be distinguished from the common limestone by its greater hardness, and by the length of time that it requires for its solution in acids; and it may be analysed by the process for carbonate of lime and magnesia. When the analytical comparison indicates an excess of vegetable matter as the cause of sterility, it may be destroyed by much pulverization and exposure to air, by paring and burning, or the agency of recently made quick lime. The deficiency of either animal or vegetable matter, must, of course, be supplied by animal or vegetable manure. The general indications of fertility and barrenness, as found by chemical experiments, must necessarily differ in different climates, and under different circumstances. The power of soils to absorb moisture, a principle essential to their productiveness, ought to be much greater in warm and dry countries than in cold and moist ones; and the quantity of fine aluminous earth they contain should be larger. Soils, likewise, that are situated on declivities, ought to be more absorbent than those in the same climate on plains or in valleys. The productiveness of soils must likewise be influenced by the nature of the subsoils, or the earthy or stony strata on which they rest; and this circumstance ought to be particularly attended to in considering their chemical nature, and the system of improvement. Thus, a sandy soil may owe its fertility to the power of the subsoil to retain water; and an absorbent clayey soil may occasionally be prevented from being barren in a moist climate, by the influence of a substratum of sand or gravel. Those soils that are most productive of corn, contain always certain proportions of aluminous or calcareous earth in a finely-divided state, and a certain quantity of vegetable or animal matter. The quantity of calcareous earth is, however, very various, and, in some cases, exceedingly small. A very fertile corn soil from Ormesten, in East Lothian, afforded in 100 parts

only 11 parts of fine calcareous earth; the finely-divided clay amounting to 45 parts. It lost 9 parts in decomposed animal and vegetable matter, and 4 in water, and exhibited indications of a small quantity of phosphate of lime. This soil was of a very fine texture, and contained very few stones and vegetable fibres. It is not unlikely that its fertility was in some measure connected with the phosphate, for this substance is found in wheat, oats, and barley, and may be a part of their food. A soil from the lowlands of Somersetshire, celebrated for producing excellent crops of wheat and beans without manure, Sir Humphrey Davy found to consist of one-ninth of sand, chiefly silicious, and eight-ninths of calcareous marl, tinged with iron, and containing about five parts in the hundred of vegetable matter. He could not detect in it any phosphate or sulphate of lime, so that its fertility must have depended principally upon its power of attracting principles of vegetable nourishment from water and the atmosphere. In some experiments made by Mr. Tillet on the composition of soils about Paris, he found that a soil composed of three-eighths of clay, two-eighths of river sand, and three-eighths of the parings of limestone, was very proper for wheat. In general, bulbous roots require a soil much more sandy and absorbent than the grasses. A very good potatoe soil, from Varsel, in Cornwall, afforded seven-eighths of silicious sand, and its absorbent power was so small, that 100 parts lost only 2 by drying at 400° Fahrenheit. Plants and trees, the roots of which are fibrous and hard, and capable of penetrating deeply into the earth, will vegetate to advantage in almost all common soils that are moderately dry, and do not contain a very great excess of vegetable matter. The soil taken from a field at Sheffield-place, in Sussex, remarkable for producing flourishing oats, was found to consist of 6 parts of sand, and 1 part of clay and finely divided matter; and 100 parts of the entire soil submitted to analysis, produced water, 3; silex, 54; alumina, 28; carbonate of lime, 3; oxide of iron, 5; decomposing vegetable matter, 4; loss, 3. From the great difference of the causes that influence the productiveness of lands, it is obvious, that in the present state of science, no certain system can be devised for their improvement, independent of experiment; but there are few cases in which the labour of analytical trials will not be amply repaid by the certainty with which they denote the best methods of melioration; and this will particularly happen, when the defect of composition is found in the proportions of the primitive earths. In supplying animal or vegetable manure, a temporary food only is provided for plants, which is in all cases exhausted by means of a certain number of crops; but when a soil is rendered of the best possible constitution and texture, with regard to its earthy parts, its fertility may be considered as permanently established. It becomes capable of attracting a very large portion of vegetable nourishment from the atmosphere, and of producing its crops with comparatively little labour and expense. For the mode of proceeding, and the instruments required in making analytical experiments on soils, we can refer the reader to the before-mentioned work of the late illustrious chemist; very accurate information on this subject will, however, be found in Dr. Ure's excellent *Dictionary of Chemistry*. But to those whose business it may be to pursue this most important of studies, in all its interesting details, we strongly recommend the perusal of the articles AGRICULTURE, in the *Oxford Encyclopædia and Supplement*, which form together an elaborate compendium of the best works on the subject in the English language, enriched throughout by the judicious observations of its learned editors.

AIGREMORE. A name given to charcoal, when in that state of preparation for the making of gunpowder, which renders it fit for the admixture of the other constituent materials.

AIGUILLE. (From the French, *needle*.) The name of an instrument used by military engineers, for piercing a rock for the lodgment of gunpowder in a mine. A similar instrument is used in the common operations of mining and the blasting of rocks.

AILERON. An abutment or starling erected in a river or strong current, to prevent the action of the water from destroying the supports of a bridge, or other building similarly circumstanced.

AIR, Atmospheric. From the remotest antiquity, until a comparatively recent period, the air was considered as one of four elements, of which all things were compounded; and it was generally held to be an invisible, imponderable, and simple substance. Some of the ancients, it is true, had vague notions of its gravitating power and of its elasticity; amongst others may be mentioned Aristotle, who says, that a bladder filled with air weighs more than when quite empty; and Hero also says, that the air, in a given cavity, may be rarefied by sucking out a part of it; but still their ideas were very imperfect, and their opinions were abandoned by their followers, for various absurd hypotheses by which they attempted to account for the phenomena produced by the action of the atmosphere. It was not until near the middle of the seventeenth century, that the real nature and properties of the atmosphere were ascertained with precision and confirmed by experiment. For these discoveries we are principally indebted to Galileo, and his pupil Torricelli. Galileo taught that the air had weight, but does not appear to have applied this idea to explain those pneumatic phenomena which were then absurdly attributed to an imaginary principle of nature, termed a horror of a void: but Torricelli following up the principle, shewed, by incontrovertible experiment, that the rise of fluids in pumps was owing to the pressure of the atmosphere, and that the height to which fluids would rise *in vacuo*, was exactly proportionate to their weight, which would, in all cases, be exactly equal to a column of air of the same base, and of the height of the atmosphere. These great principles were successfully followed up by various eminent philosophers, and numerous important conclusions and useful applications of them were the result. Towards the close of the nineteenth century, the air was discovered to be a compound of two gases, to which the names of oxygen and azote were given, and this discovery served as the basis of the modern system of chemistry, which has been so fertile in brilliant scientific results. Under the articles Chemistry and Pneumatics will be found the demonstrations of the chemical and physical properties of the atmosphere; we shall, therefore, in this place, merely state what are its principal characteristics, and the uses to which they are made subservient in many processes of the arts and manufactures. Air, then, is an invisible elastic and ponderable gaseous fluid, its bulk and density depending upon its temperature, and the pressure to which it is exposed. Under a pressure of 30 inches of mercury, and at a temperature of 60° Fahrenheit, its spec. grav. as ascertained with great care and accuracy by Messrs. Arago and Biot, is .00122, water being 1.00000, or it is 820 times lighter than water; and if we take a cubic inch of water to weigh 252.525 grains, then 100 cubic inches of air will weigh 30.808 grains, and a cubic foot will weigh 532.36 grains. Mariotte ascertained that its bulk is inversely as the pressure, a double pressure reducing a given volume to half its bulk. The applicability of this law to air under very great pressure, has been questioned, but not satisfactorily disproved; and for all practical purposes it may be safely received; whilst, from its simplicity, it may be remembered with ease and applied with facility. Air expands by an increase of temperature, the rate of expansion is not exactly equal for equal increments of heat, but on an average, the increase of bulk above 32° Fahrenheit is $\frac{1}{480}$ of its bulk, for each degree of heat on the same scale. The expansion or rarefaction of air is accompanied by a decrease of its temperature, and in its condensation or compression, it gives out a proportional quantity of heat. Air can take up and hold in solution a portion of water depending upon the temperature.

AIR-PUMP. An instrument or machine for exhausting or rarefying the air in closed vessels, and very generally employed to illustrate the properties of air, and to explain the various phenomena connected with the science of pneumatics. The inventor of the air-pump was Otto Guericke, a magistrate of Magdeburgh; his machine was of a rude and inconvenient structure, and worked under water, but a description of it having been received by Mr. Boyle, he, with the assistance of Dr. Hock, introduced such improvements in the construction as to render the machine extremely serviceable in philosophical experiments upon the nature and properties of the atmosphere. Numerous improvements have since been made by Hawksbee, Gravesand, Smeaton

Prince, and others; but more especially by Mr. Cuthbertson, whose arrangements are so excellent as to claim a particular notice and description.

Fig. 1.

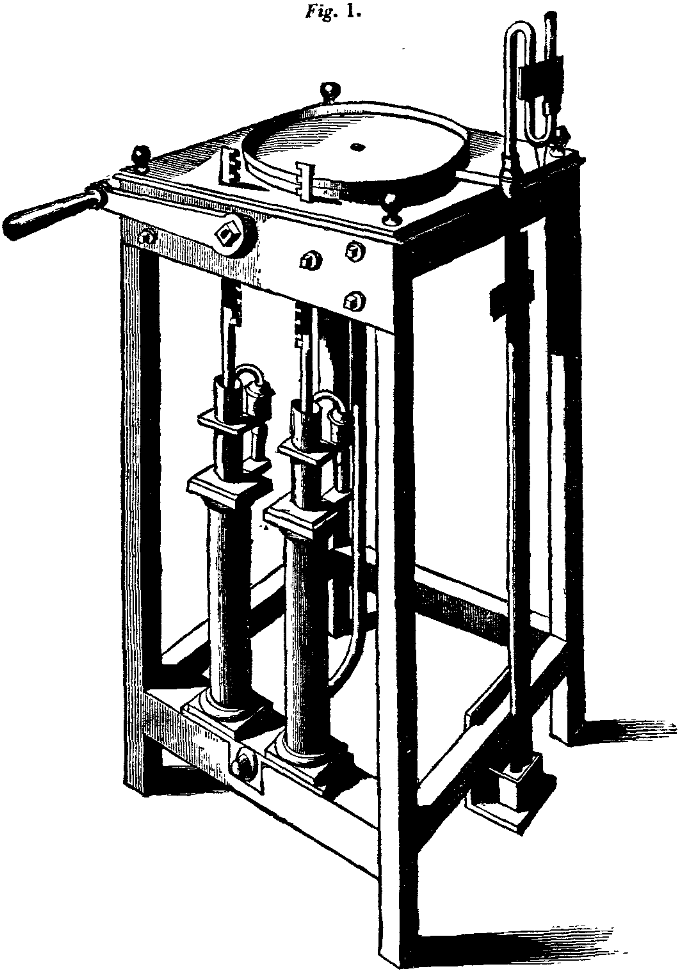


Fig. 1 represents a perspective view of the machine, with its two principal gauges screwed into their places, which need not, however, be used together except in cases requiring the utmost exactness; but in common experiments, one of them is removed, and a stop-cock put in its place. *Fig.* 2 is a section of one of the barrels, with all its internal parts; *Fig.* 3 a section of the piston; and *Figs.* 4 and 5 parts of the piston, shewn detached for the sake of perspicuity. In *Fig.* 2, C D represents the barrel, F the collar of leathers, G a hollow cylindrical vessel to contain oil; R is also an oil-vessel to receive the oil which is drawn along with the air from the barrel when the piston is drawn upwards, and when this vessel is full the oil is carried over with the air along the tube T into the oil vessel G; *c c* is a wire which is driven upwards from the hole, by the passage of the air, and as soon as this has escaped, it falls down again by

its own weight, shuts the hole, and prevents the return of the air into the barrel; at *d* are fixed two pieces of brass to keep the wire *c c* in a vertical position, in order that it may accurately shut the hole. H is the piston rod, having a rack on the upper end, and made hollow to receive a long wire *g*, which opens and shuts the hole L; on the lower end of this wire is screwed a nut *o*, which, by stopping in the narrowest part of the hole, prevents the wire *g* from being drawn up too far. This nut and screw are seen more distinctly in *Fig.* 3; the wire slides in a collar of leathers shewn in*Figs.* 3 and 5 in the middle piece of the piston. *Figs.* 4 and 5 are the two main pieces which compose the piston, which is shewn entire in *Fig.* 3; *Fig.* 5 is a conical piece of brass having a shoulder at bottom; a long hollow screw is cut about two-thirds of its length, and the remaining part of the hole, in which there is no screw, is about the same diameter as the screwed part, except a thin plate at the end, where the diameter of the hole is just equal to that of the wire *g g*. That part of the inside of the conical brass in which no screw is cut, is filled with oiled

Fig. 3.

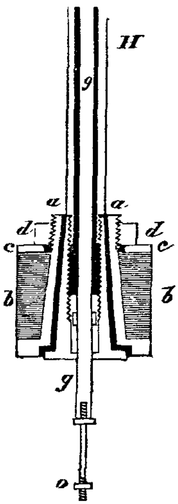


Fig. 4.

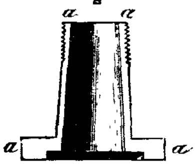


Fig. 5.

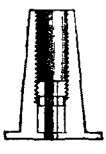
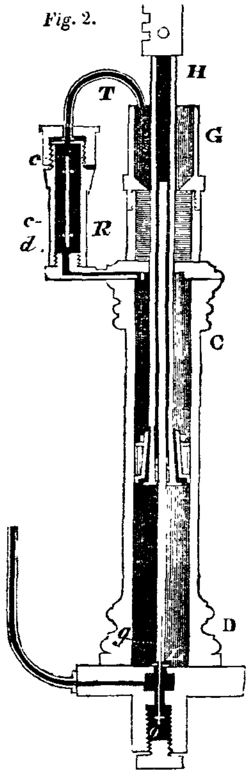


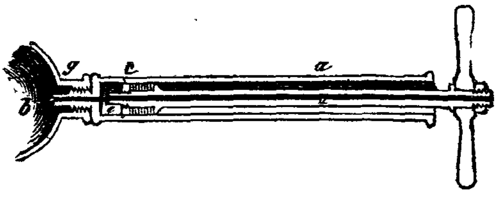
Fig. 2.



leathers, having holes in them, through which the wire can slide stiffly; a short external screw, working in the internal screw, and a washer with holes in them, through which the wire *g* passes, serve to compress the leathers. *a a Figs.* 3 and 4 is the outside of the piston, the inside of which is turned so as exactly to

fit the outside of *Fig.* 5; *b b*, *Fig.* 3, are round leathers, about 60 in number of the same diameter as the barrel C D, and having holes in the centre to receive *a a;* a circular plate, or washer, *c c*, *Fig.* 3, is placed over the leather, and a nut *d d*, upon a screw cut upon the upper end of *a a*, serves to compress them. The piston rod H is screwed into the middle piece of the piston, *Fig.* 5, and when drawn upwards, it will cause *Fig.* 5 to shut close into *Fig.* 4, and drive out the air above it; but when pushed down it will open as far as the shoulder on the rod will allow, and permit the air to pass between *Figs.* 5 and 4. Having thus described at large the several parts of this machine, we proceed to explain the process of rarefaction, which is carried on in the following manner:—Conceive the piston to be at the bottom of the barrel, the inside of which contains common air. Now when the rod is drawn up, the upper part of the piston sticks fast in the barrel, till the conical part connected with the rod shuts the conical hole, and its shoulder applies close to its bottom. The piston being now shut, the whole is drawn up by the rack-work driving the air before it through the aperture, into the oil vessel at *r*, and out into the atmosphere by the tube T. The piston will then be at the top of the barrel, and the wire *g* will stand nearly as shewn in the figure, just raised from the hole L, where it is prevented from rising higher by the nut O. During this motion, the air will expand in the receiver, and come along the bent tube into the barrel; by this means the barrel will be again filled with air, which, as the piston rises, will be rarefied in the proportion of the capacity of the receiver, pipes, and barrel together, to that of the latter alone. When the piston is moved down again by the rack-work, it will force the conical part, Fig. 5, out of the hollow part, *Fig.* 4, as far as the shoulders *a a*. *Fig.* 3 will rest on *a a*, *Fig* 4, which will then be so far open as to permit the air to pass freely through it, while at the same time the end of *g g* is forced against the top of the hole, and, by shutting, prevents any air from returning into the receiver; thus the piston moving downwards suffers the air to pass out between the sides of *Figs.* 4 and 5, and when it is at the bottom of the barrel, it will have the column of air above it, and, consequently, when drawn up, it will shut and drive out the air, and by opening the hole at L, will at the same time give a free passage to more air from the receiver. This process being continued, the air of the receiver will be rarefied as far as its expansive powers will permit, for in this machine there are no valves to be forced open by the elasticity of the air in the receiver, which at last it is unable to effect; there is, therefore, nothing to prevent the air from expanding to its utmost degree, which is the peculiar excellency of this construction.

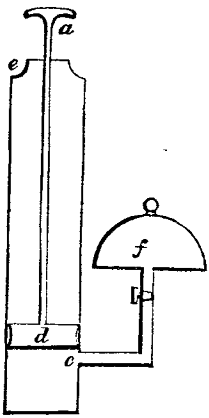
Although the machine just described is equally adapted for condensing air as for rarefying it, by merely connecting the bent pipe with the oil vessel R, instead of the lower part of the pump, yet as the former operation seldom requires the same delicacy of process, it is frequently effected by a simpler machine, termed a condensing syringe. The following description will give an idea of the ordinary construction of this instrument. *a* is a cylindrical tube of



small diameter, open at one end, the other end perforated with a very small hole *b*, and being turned externally to a very small cylinder. A strip of bladder, or of thin leather, soaked in a mixture of oil and tallow, must be tied over the hole. On the end of the cylinder is cut an external screw, to attach it to the vessel in which the air is to be condensed. *c* is the piston moving air-tight in *a; d*, the piston rod screwing into *c;* this rod is perforated with a small hole throughout

its length, the lower end of the hole having a valve *e*, similar to the valve *b* in the cylinder, and opening into the cylinder. To the upper end of the rod is fixed a handle. *g* is the neck of the receiver, having a hollow screw fitting the solid screw on the end of the cylinder. Now when the piston is drawn up, a void is left below it, and the external air rushing through the perforation of the piston rod, opens the valve *e*, and fills the cylinder. Then, on pushing down the piston, the valve *e* closes; the air being compressed into less space, presses on the valve *g*, shuts it, and none escaping through the piston, it is gradually condensed as the piston descends till it opens the valve *b*, and is added to the air already accumulated in *g*. We may thus force into the vessel any quantity of air consistent with its strength; and if the receiver be furnished with a stop-cock, the cock may be turned, and the receiver be detached from the syringe, and thus be in a state to be transferred to any other purpose required. In all cases where considerable force is required, and, consequently, a great condensation of air, it will be requisite to have the condensing syringe of small bore, perhaps not exceeding half an inch diameter, otherwise the force requisite to produce the compression will become so great, that the operator will not be able to work the machine; for as the pressure against each square inch is about 15 lbs. for each additional volume of air forced into the receiver, and 12 lbs. upon each circular inch, if the syringe be of 1 inch diameter, it will require a force of 120 lbs. to condense ten volumes of air into the barrel, whereas with a half-inch bore it would only require 30 lbs.

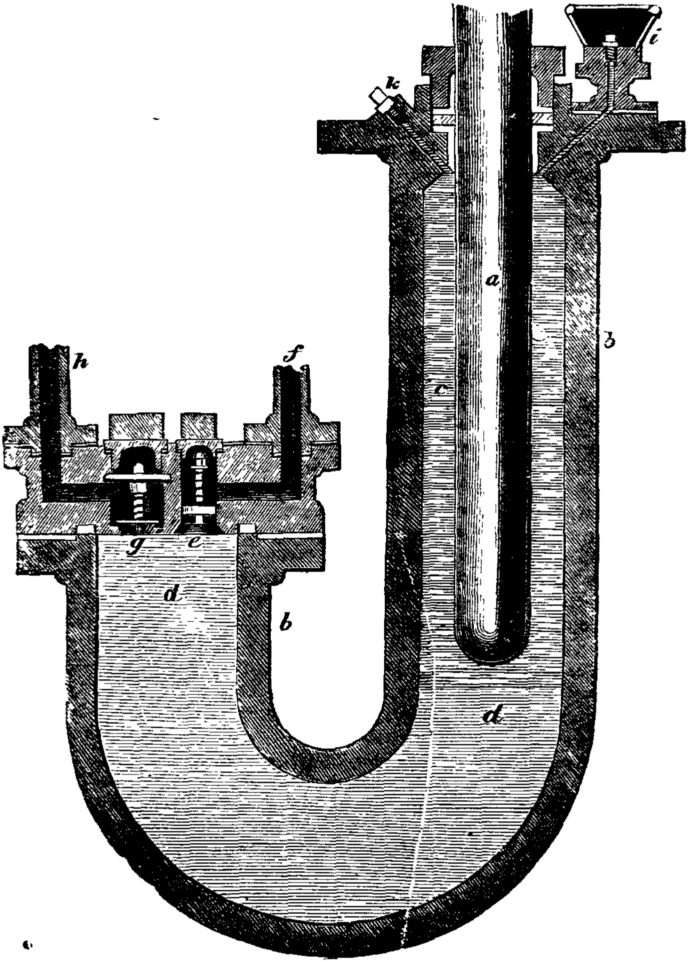
We insert the following description of an air-pump on account of its extreme simplicity. It is the invention of Mr. W. Ritchie, and has no artificial valves, which, as commonly constructed, are very liable to be deranged, and the repairs are attended with considerable trouble and expense. The machine consists of a barrel shut at the lower end, and having a small aperture at *c*, forming a free communication with the receiver at *f*; the piston *d* is solid, and stuffed in the usual way. The piston rod works in a small stuffing-box at *a*, so as to render it completely air tight. There is a small aperture at *e*, in the top of the barrel, to allow the air to make its escape when the piston is raised. The air-pump may be worked in the usual way, or by the method of continued motion. In commencing the exhaustion of the receiver, the piston is supposed to be below the small aperture at *c*. The piston is then raised, and the air which occupied the barrel is forced out through the aperture at *e*. The point of one of the fingers is applied to the perforation in the same manner as in playing the German flute. The air easily passes by the finger which, when the piston begins to descend, shuts the opening, and completely prevents the entrance of the external air. The piston is again forced down below the opening *c*, the air in the receiver rushes into the barrel, and is again expelled by the ascending piston.



Since the air in the receiver has no valve to open by its elasticity, it is obvious that there is no limit to the degree of exhaustion, as in the common construction. For a long time the use of the air-pump was confined to the purposes of philosophical experiment: the first application of it to mechanical purposes was made by Bolton and Watt, in their steam engines, where it is used for drawing off the air extricated from water by boiling, as also the water used for condensing the steam; and about twenty years ago, the Hon. E. Howard availing himself of a well-known principle, that liquids enter into ebullition at a much lower degree of temperature in vacuo, than when under the pressure of the atmosphere, introduced a most important improvement in the process of sugar refining, by concentrating the syrup in close vessels, in which a vacuum is maintained by means of an air-pump; and subsequently, Messrs. Allen & Co. of Plough Court, have adopted the principle in preparing the more delicate medicinal extracts. A patent has also been taken out for more speedily tanning leather, by enclosing

the skins in boxes, and exhausting the air from the upper surface of the skins, whilst the lower surface is exposed to the tanning liquor, which is forced into the pores by the pressure of the atmosphere. Dr. Church, of Birmingham, also has a patent for improvements in casting metals, which consists in exhausting the air from the moulds; and patents have been taken out for distillation in vacuo, all of which applications of the air-pump we propose to explain in detail when we come to treat of the above-named manufacturing processes.

In the description of Cuthbertson's air-pump it was stated that it was equally applicable to the condensation of air, as to its exhaustion. We now present to our readers a condensing air-pump of a different description, which is the invention of the late Mr. D. Gordon, of the Portable Gas Works, where it was used for compressing the gas into the portable gas-holders, and will be found

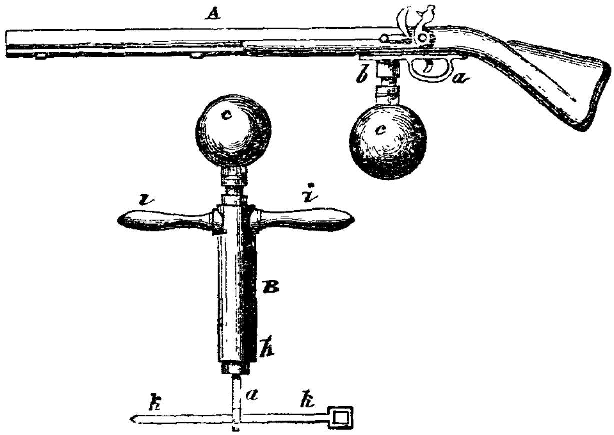


very effective in subjecting any air or gas to a great compression, as the whole volume of gas taken into the pump at each stroke is effectually discharged, the mercury employed in the pump completely excluding every portion from below the delivery valve. The figure represents a vertical section of one of the pumps

with the plunger *a* at its lowest immersion, or down-stroke, as it is called. At this moment of time every part of the syphon is completely filled with the fluid it contains to the entire exclusion of atmospheric air, the deeply shadowed part *c* being water, and the lighter tint, quicksilver. It will therefore be easily conceived that when the plunger is withdrawn by the up-stroke, an empty space or vacuum, equal to the cubic admeasurement of the plunger, will be left in the syphon; and as mercury is a much heavier body than water, the latter is pushed up by the former, and follows the plunger as it ascends. The mercury, consequently, sinks below its present level, which causes the "suction valve" *e* to open, and to let in a volume of gas at the ordinary pressure, which flows from a gasometer, or gas-holder, through the pipe *f*. At the down-stroke of the plunger, the gas is then compressed and forced through the discharge valve, (which opens only outward) into the pipe *h*, which leads to a strong recipient into which the gas is condensed. The action of the pumps being continued, the compression of the gas is effected to whatever degree may be required, provided the power of the gas engine, or other first mover, be adequate. In the Portable Gas Works above-mentioned, there were recently nine pumps in operation, worked by a 10-horse engine. The quicksilver and water are poured into the syphon by means of the basin and perforation at *i*, the aperture at *k* being opened to allow the air to escape; the aperture *k* is next made perfectly tight by a plug, which is screwed into the orifice, during which time the water is continually being poured in at *i*, to expel the air completely, and fill up every crevice with the fluid; another plug is then screwed into the orifice at *i*, with the water above it. After this, the first down-stroke of the plunger expels the atmospheric air on the surface of the mercury, in the short leg of the syphon, and the pump is then ready to perform the office of alternately drawing in the gas from the gas-holder, and compressing it into the portable lamps. The gas sent out by the company is compressed into $\frac{1}{30}$ of its original volume.

AIR-GUN. A machine in which highly-compressed air is substituted for gunpowder to expel the ball, which will be projected forward with greater or less velocity, according to the state of condensation, and the weight of the body projected. The effect will, therefore, be similar to that of a gun charged with gunpowder, for inflamed gunpowder is nothing more than air very greatly condensed, so that the two forces are exactly similar. The elasticity of the air generated by the inflammation of gunpowder has been estimated by Mr. Robins as equal to about 1000 times that of common air; it would therefore be requisite to condense air into one-thousandth part of its original bulk to produce the effects of gunpowder. There is, however, this important consideration to be attended to, viz. that the velocities with which balls are impelled are directly proportional to the square root of the forces; so that if the air in an air-gun be condensed only ten times, the velocity will be equal to $\frac{1}{10}$ of that arising from gunpowder; if condensed twenty times, the velocity would be $\frac{1}{7}$ that of gunpowder, and so on. Air-guns, however, project their balls with a much greater velocity than that assigned above, and for this reason, that, as the reservoir or magazine of condensed air is commonly very large in proportion to the tube which contains the ball, its density is very little altered by passing through that narrow tube, and consequently the ball is urged all the way by nearly the same force as at the first instant; whereas the elastic fluid arising from inflamed gunpowder is but very small indeed in proportion to the tube or barrel of the gun, and therefore by dilating into a comparatively large space as it urges the ball along the barrel, its force is proportionally weakened, and it always acts less and less on the ball in the tube. Hence it happens, that air condensed only ten times into a pretty large receiver, will project its ball with a velocity little inferior to that of gunpowder. Having thus explained the principle of the machine, we shall proceed to describe the construction of one: that by Martin is perhaps the best, and is as follows:— It consists of a lock, stock, barrel, ramrod, &c. of about the size and weight of a common fowling-piece. Under the lock at *b* is screwed on a hollow copper ball *c*, perfectly air-tight. This ball is fully charged with condensed air, by means of the syringe B, previous to its being applied to the tube at *b*. Being charged and screwed on as above stated, if a bullet be rammed down in the

barrel, and the trigger *a* be pulled, the pin in *b* will, by the spring-work in the lock, forcibly strike out into the ball, and thence by pushing it suddenly, a valve within it will let out a portion of the condensed air, which, rushing through the aperture in the lock, will act forcibly against the ball, impelling it to the



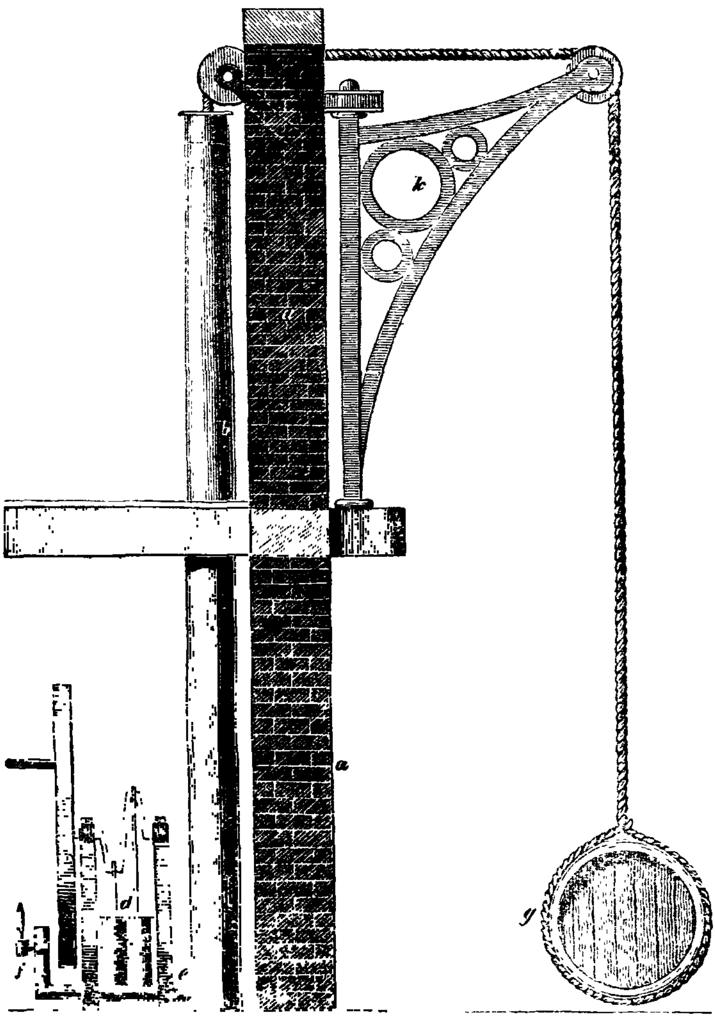
distance of 60 or 70 yards, or further, if the air be strongly compressed. At every discharge only a portion of the air escapes from the ball; therefore, by re-cocking the piece another discharge may be made, which may be repeated for a number of times proportioned to the size of the ball. The air in the copper ball is condensed by the syringe B in the following manner. The ball is screwed quite close on the top of the syringe; at the end of the steel-pointed rod *a* is a stout ring, through which passes the rod *k;* upon this rod the feet should be firmly set; then the hands are to be applied to the two handles *i i* fixed on the side of the barrel of the syringe, when, by moving the barrel B steadily up and down on the rod *a*, the ball *c* will become charged with condensed air, and the progress of condensation may be estimated by the increasing difficulty in forcing down the syringe. At the end of the rod *k* is usually a square hole, that the rod may serve as a key for attaching the ball to either the gun or syringe. In the inside of the ball is fixed a valve and spring, which gives way to the admission of the air, but upon its emission, comes close up to the orifice, shutting out the external air. The piston rod works air-tight by a collar of leather on it, in the barrel B; it is therefore obvious that when the barrel is drawn up, the air will rush in at the hole *h;* when it is pushed down, it will have no other way to pass from the pressure of the piston but into the ball *c* at the top. The barrel being drawn up, the operation is repeated, until the condensation is so great as to resist the action of the piston. If air be very suddenly compressed into a small compass, the heat given out is so considerable, as to be sufficient to ignite inflammable substances. This discovery was made, accidentally, by a French soldier, who, in cleaning his musket with some wadding fastened to the ramrod, found, after thrusting the ramrod suddenly down the piece, that the wadding had ignited. The fact he communicated to the National Institute, and repeated the experiment in their presence. This property has been turned to advantage in an apparatus denominated, "An Instantaneous Light Machine," constructed in a walking stick, which consists of a piston accurately fitted and worked in a cylinder, by the sudden stroke of which the volume of air contained in the cylinder becomes so much compressed as to give out sufficient heat to set fire to a piece of the substance termed German tinder. A patent was also taken out in 1826, by Mr. Newmarch, of Cheltenham, for a similar method of exploding fire-arms, by means of a cylinder and piston, enclosed in the stock behind the breech, which has a small hole, closed by a

valve. The piston is forced back, by means of a lever, against a powerful spring, and upon being released, is impelled forward into the cylinder with such force, as to cause the air before it to give out its caloric in the state of sensible heat or fire at the aperture in the breech, which passing the valve, enters the barrel, and instantly ignites the charge of powder.

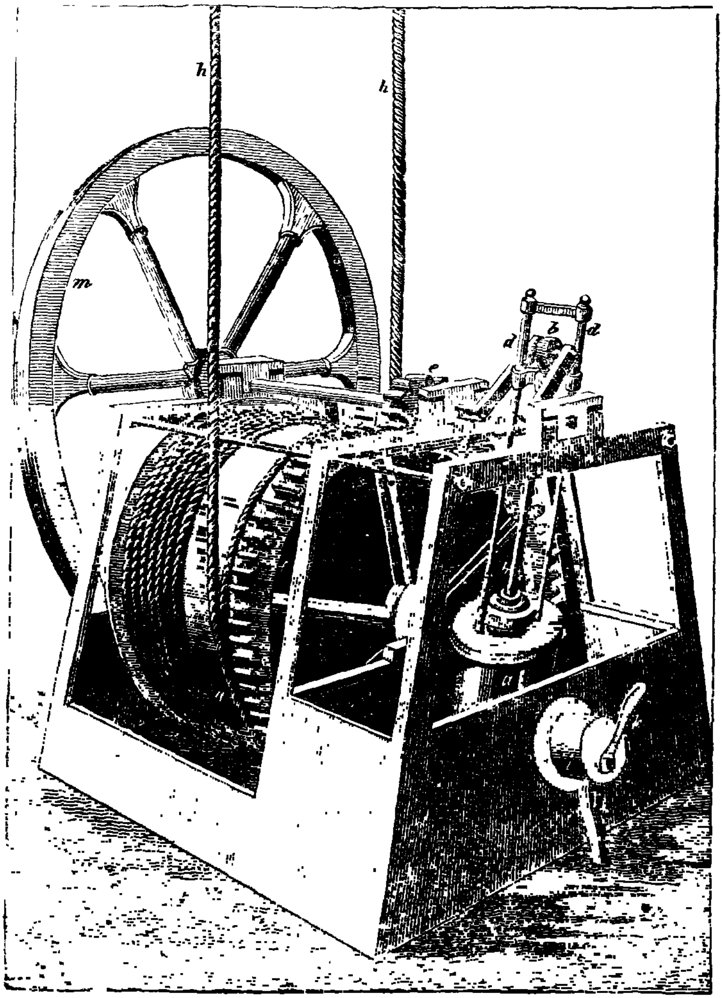
AIR-PRESSURE ENGINES. Engines in which the difference of pressure of air of different densities is employed as a motive force. From the extreme lightness and mobility of air, it has been frequently proposed to employ it as a medium for transmitting motion to machinery at a considerable distance from the prime mover. Amongst the first who attempted this, is the celebrated Papin, who invented the steelyard safety-valve. He employed a fall of water to compress the air in a cylinder, through the medium of an intervening piston; and he connected this cylinder to another, at the mouth of a mine a mile distant, by means of a pipe of that length. In the second cylinder was another piston, the rod of which was intended to work a set of pumps; but contrary to expectation, the compression of the air in the first cylinder produced no movement in the piston of the second. Papin subsequently attempted to bring his scheme into use in England, but did not succeed. Afterwards, however, he erected great machines in Auvergne and Westphalia, for draining mines, but so far from being effective machines, they would not even begin to move. He attributed the failure to the quantity of air in the pipe, which must be condensed before it can condense the air in the remote cylinder; he therefore diminished the size of this pipe, and made his water machine exhaust instead of condense, and had no doubt that the immense velocity with which air rushes into a void, would make a rapid and effectual communication of power. But the machine stood still as before. Near a century after this, an engineer at an iron foundry in Wales, erected a machine at a powerful fall of water, which worked a set of cylinder bellows, the blow-pipe of which was conducted to the distance of a mile and a half, where it was applied to a blast furnace; but notwithstanding every care to make the conducting pipe very air-tight, of great size, and as smooth as possible, it would hardly blow out a candle. The failure was ascribed to the impossibility of making the pipe air-tight; but above ten minutes elapsed after the action of the piston in the bellows, before the least wind could be perceived at the end of the pipe, whereas the engineer had calculated that the interval would not exceed six seconds. The foregoing particulars are taken from Dr. Robinson's *Natural Philosophy*, art. *Pneumatics*, and an explanation is offered of this curious phenomenon; but on account of its prolixity, we omit it; but the following remarks, which appeared in the Franklin Journal, are deserving of notice. "If we take a particular care, and calculate the resistance of air moving through pipes according to acknowledged principles, we shall find nothing mysterious in the above result. It will be found, that if the blow-pipe is 3 inches in diameter, and only a mile long, the air at one end must be kept constantly condensed by a pressure equal to $5\frac{4}{10}$ atmospheres to produce a velocity of 128 feet per second; and yet this velocity gives only 2304 gallons per minute, only about half the quantity used in the furnaces of Europe; a blast furnace there expels 720 cubic feet of air per minute, (*Mech. Philos.* Vol. VIII. p 784,) if we calculate the velocity of water issuing from a pipe a mile long, and 3 inches in diameter, under a 9-foot head and fall, to be 1 foot per second. Now, as equal velocities are known to be generated in all fluids by equal heads, all other circumstances being equal, it will follow that a 9-foot head of air, or $\frac{1}{800}$ of a head of 9 feet of water, will generate in air a velocity of 1 foot per second in a tube 3 inches in diameter, and a mile long. Again, it is known both from theory and experiment, that the heads of pressure generating velocities in fluids, are as the squares of the velocities; now the square of 1 is 1, and the square of 128 is 16,384, therefore the head of pressure due to the velocity of 128 feet, is obtained by the following proportion, as 1 : 16384 :: 9 : 147456, and this number divided by 800, gives $184\frac{1}{3}$ equal to a pressure of $5\frac{4}{10}$ atmospheres, as before said: now if we suppose this velocity doubled, or 256 feet a second, in order to discharge air enough for a blast furnace, the head of pressure must be four times as great, or

upwards of 21 atmospheres. This would require a machine of 3426 horse power, provided a horse can work eight hours a day, raising 140 lbs. 200 feet per minute. Notwithstanding the failure of both of the plans of Papin, and the plausible arguments against them just quoted, they have been recently revived in this country. Mr. Samuel Wright has taken out a patent for transmitting power to machinery by means of condensed air; but we have not heard of any erections on the principle. Mr. Hague, however, has taken out patents for effecting the same object by the rarefaction of air by an air-pump, and has established several machines upon this principle, the successful operation of which leaves no doubt that the failure of Papin must have arisen from some defective arrangements, or imperfect workmanship. We have selected a few of those machines to which Mr. Hague considers the principle as peculiarly applicable. The first of these which we shall describe, is a crane for raising goods into lofty warehouses; but previous to showing the actual arrangement of the machinery, we shall explain the principle by means of the accompanying figure.

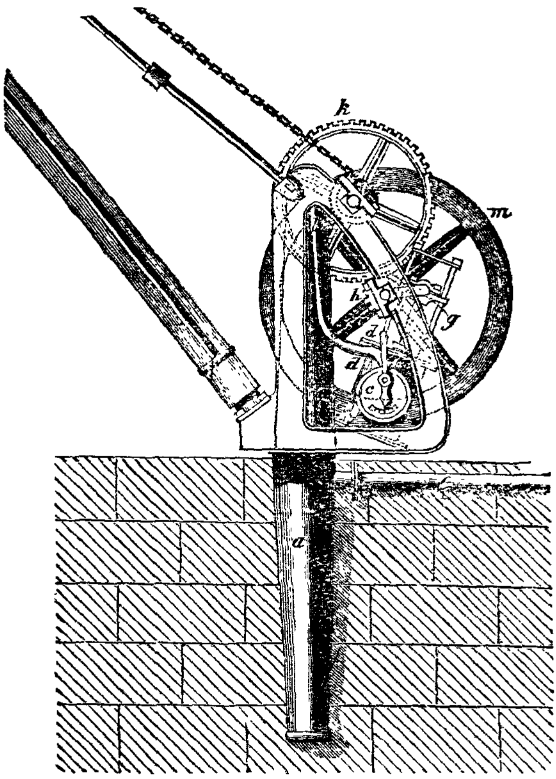
Air-Pressure Engine, A.



a represents the side of a warehouse; *b* a cylinder truly bored, and fixed vertically to the wall; *c* a piston fitting air-tight in the same cylinder, and suspended from a rope or chain passing over the jib *k*; *g* a load attached to the rope; *d* a double-barrelled air-pump worked by the two cranks which may be turned by hand or by steam; *e* a pipe of communication between the air-pumps and the cylinder, and fitted with a cock *f*. Now if the pumps be set in motion, the air in the cylinder will become more and more rarefied, and the pressure of the external air will at length so far exceed the internal pressure, as to cause the piston to descend, and, consequently, to raise the load *g*. But this would be an exceedingly inconvenient form; for the machine, in its powers, would be confined within very narrow limits by the largest cylinders which could be constructed; but in the excellent arrangements of Mr. Hague, which we now proceed to describe, it will be seen that any load, however great, may be raised to any required height. In the subjoined engraving *a* represents a

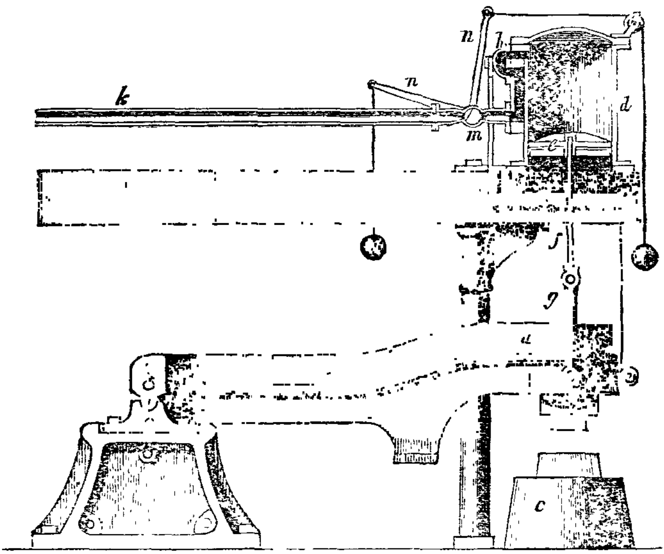


working cylinder vibrating upon gudgeons, one of which has passages leading to the top and bottom of the cylinder; *b* piston rod connected to the crank; *d d* guide rods; *e* pinion on axis of the crank, driving *f* a toothed wheel on the axis of the drum *g*; *i* the valve-box, in which the hollow gudgeon of the cylinder turns, and, admitting the atmosphere to press upon one side of the piston whilst the air is drawn from the opposite side by an air-pump worked by a steam-engine; *k* the spanner for reversing and regulating the motions of the machine; *l* pipe leading to the air-pump; *m* fly-wheel.



The above figure represents a swing-round crane, upon the same principles as the former, and may be supposed to form one of a range round a dock basin. *a* is a hollow cast-iron post, upon which the crane turns, and is firmly imbedded in masonry; from the upper end proceeds a pipe *b* turning air-tight in a stuffing-box, and communicating with a cylinder *d* by means of a three-way cock *c*. The cylinder vibrates upon gudgeons, in one of which are formed two hollow passages, the one leading to the top, and the other to the bottom, of the cylinder. A pipe *e* proceeds from an aperture *f* in the crane post to an air-pump, worked by a steam-engine, or any other power, and which may be situated in any part of the docks, the air being rarified alternately above and below the piston of the vibrating cylinder, whilst the atmosphere presses upon the opposite side of the piston; the alternate motion of the latter turns the crank *g* and the piston *h*, which drives the wheel *k* fixed upon the axis of the chain barrel *l*, and thus raises the load; *m* is a fly-wheel, by means of which the reciprocating motion of the cylinder imparts a rotatory action to the crank.

The last example we shall give of the application of Mr. Hague's patent, is that of a tilting or powerful forge-hammer, which is raised by the atmosphere pressing upon a piston connected to the hammer, (the air on the opposite side being rarefied by means of an air-pump situated at a distance,) and which falls, by its own weight, upon the admission of the atmosphere above the piston.

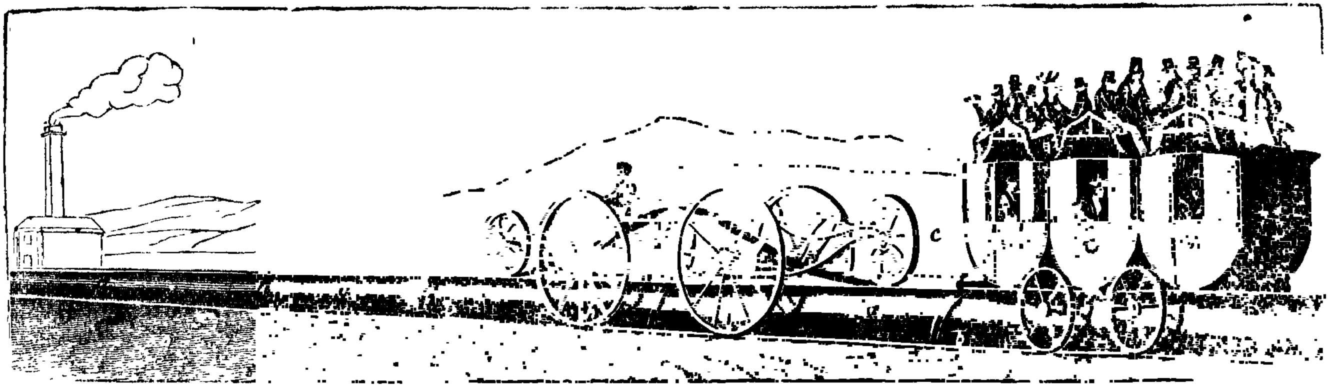


a b is the hammer turning upon a fulcrum at *b*; *c* the anvil; *d* a cylinder, situated immediately over the hammer; *e* the piston, connected with the hammer by the bar *f*, and the slings *g*; *h* a slide valve, worked by the lever *l*, which is struck by a pin on the bar *f*, when the piston arrives at the top of the cylinder, which depresses the valve so as to shut off the communication with the air-pump, and admit the atmosphere, permitting the hammer and piston to fall by their own weight. Towards the close of the descent, the hammer, by means of a line attached to it and to the lever *l*, reverses the position of the lever *l* and of the slide-valve, thus re-opening the communication between the cylinder and air-pump. *k* is the pipe leading from the cylinder to the air-pump, and *m* a cock for shutting off the communication with the air-pump when the hammer is not at work; *n n* spanners for opening and shutting the cock.

Pneumatic Transport.—In the year 1824, the ingenious Mr. John Vallance, of Brighton, took out a patent for a mode of employing the natural pressure of the atmosphere, operating upon a partial vacuum, for the purpose of transporting persons and goods with extraordinary rapidity from place to place. He proposed to construct hollow cylinders of cast-iron, sufficiently large to allow carriages with passengers and goods to pass through them. A series of these cylinders were to be united, and extend from town to town, and the junctions made sufficiently air-tight to admit of a rarefaction of the air within the tube, by the continued action of powerful exhausting machinery at one end. The carriages, which were to travel inside of this tube, were to be of the same cylindrical form, and very nearly of the same transverse dimensions, so as to constitute, in effect, pistons, which were to be impelled by the air rushing in at one end of the trunk, to restore the equilibrium, or fill up the vacuous space mechanically produced on the opposite side of the pistons. A model, on a sufficiently large scale to test the efficacy of the principle and mode of action, was set up on the patentee's premises at Brighton, and many persons were thus *blown*

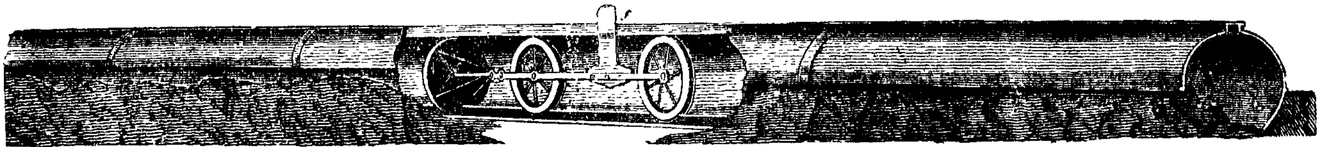
through the tube. Notwithstanding this demonstration of the correctness of the principle, sufficient subscriptions were not obtained to carry the plan into effect on a greater scale. A notion was very generally entertained that the scheme, if feasible, could not be carried into practice on an extensive scale, and at a cost that would repay the subscribers; to this circumstance may also be added, a fear that the extraordinary mode proposed, of travelling in the interior of a tube, would not accord with the taste of the public. The latter objection has, however, been obviated by a novel arrangement of mechanism, which has recently been the subject of a patent granted to Mr. Henry Pinkus, whose invention consists in transferring the action produced upon a piston or diaphragm, moving in the interior of a tunnel or tube, to its exterior, by connecting a vehicle or machine, (termed the dynamic traveller,) situated within the tube, with a car or carriage without, (denominated the governor,) to which the train of transport carriages are attached. A working model of this invention is at present being exhibited in Wigmore-street, Cavendish-square; and a joint-stock company, called "The National Pneumatic Railway Association," is in progress of formation; the avowed object of which is to carry the plan into effect on all the principal roads of the kingdom. This singular mode of transport having thus gained considerable celebrity, and the principle upon which it is founded being essentially correct, we shall (notwithstanding the mechanical difficulties apparently to be surmounted) introduce a brief description of the invention under this head, reserving a more extended consideration of the subject for the article RAILWAY. The pneumatic railway admits of several methods of application, in each of which the dimensions, economy, and details, vary. On a line of road where the transit is very great, as, for example, between Liverpool and Manchester, a double line would be required, the cylinders of which, the patentee states, should be 36 inches in diameter, and so moulded, as to be of the average thickness of three-quarters of an inch; that is, the lower semi-circumference to be three-quarters of an inch, and enlarged into a series of rings three feet apart, so as to be 1¼ inch thick where the rings occur; thus giving the lower semi-circumference an average thickness of seven-eighths of an inch. The upper semi-circumference need not be of a greater average thickness than five-eighths of an inch, when disposed into similar rings. On a single line of road, where the transit is considerable, the size of the cylinders may be increased to 40 inches diameter, and be of a proportionate thickness; but when the pneumatic system is combined with a common railroad, that is, laid between the ordinary rails, as a medium for transmitting motive power to carriages running in the usual manner on rails fixed upon blocks, the cylinder not having to sustain the weight or action of the loaded carriages, may be reduced to 28 inches diameter, and half an inch thick: and when the system is applied to draw or propel barges on canals, (which is also contemplated by the patentee,) a cylinder of only 22 inches diameter, laid down in the towing-path, he considers to be fully adequate. The length of the pneumatic tube will be equal to the whole length of the railway or canal to which it may be applied, and it should be cast in portions of the greatest length possible, in smooth metal moulds, so that their inner sides should be very even and true, and they are to be connected by the ordinary socket joint. *Fig.* 1 of the annexed wood-cuts exhibits a perspective sketch of a portion of a line of pneumatic railway, laid down, exhibiting the "governor" drawing a train of carriages along it. The upper half only of the air tunnel *a a* is seen, the other half being imbedded in a semicircular trench; on the edges of which trench rest strong projecting ledges, which are cast to the outsides of the tunnel, in a longitudinal direction. These ledges are about three inches wide on their upper surfaces, and constitute the railway upon which the wheels *h h* of the governor or drag, and those of the train, run. To explain the mode adopted of communicating the motive force generated in the interior of the tunnel to the governor on the outside, we must refer the reader to *Fig.* 2, which represents a sectional perspective of a portion of the tunnel; wherein it will be seen that a strong flat bar *f* is bolted to the governor, so as to depend vertically through a longitudinal chase made in the top of the tunnel, and reaching to the centre

Fig. 1.



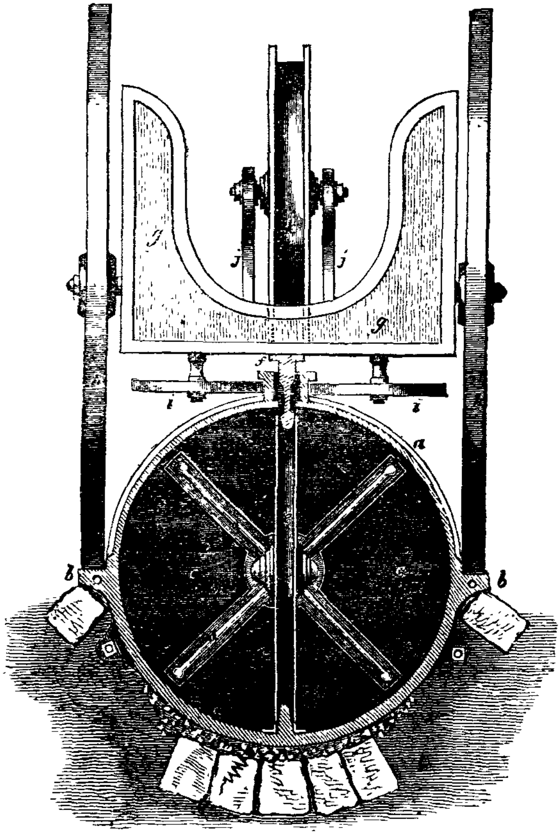
Perspective sketch of a portion of a line of the pneumatic railway, exhibiting the governor dragging a train of carriages along it,—representative of the working model referred to in the text

Fig. 2.



Perspective view of the tunnel only, with the lowermost half imbedded in the earth; the central portion of the figure being broken away to show the pneumatic piston: its attachment to the dynamic traveller, and the connexion of the latter by the vertical bar *f* to the governor, on the outside, seen in *Fig.* 1, at *g*.

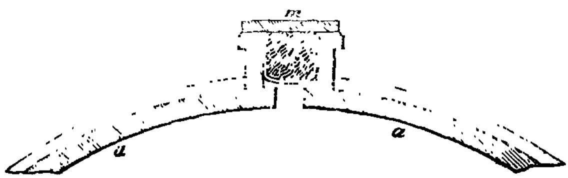
of it. Here it is firmly fastened to a species of carriage, of the form of a velocipede, which operates as a guide and stiffening-frame to the piston or diaphragm *c*, that receives the impulse of the atmosphere; the expanding piston having a conical steel ring around its periphery, one foot wide, and placed at an angle of about 15° from the surface of the cylinder, against which one edge of the cone acts with a slight pressure of the air, so as to conform to any slight inequality of the cylinder. A more exact comprehension of these arrangements will be afforded by the subjoined *Fig.* 3, which exhibits a transverse section of the pneumatic



railway, an end elevation of the governor; its connexions and position; also the rear wheel of the dynamic traveller; its position within the cylinder; the guide rail (cast to the interior of the cylinder) on which it runs; and the piston in advance. *a a a* is the cylinder, the lower semi-circumference of which is of greater thickness than the upper, to enable it to withstand the greater strain on this part, to which it is subjected by the weight of the carriages rolling upon the projecting ledges or rails *b b*; *c c c* shows the area of the piston strengthened by cross bars; *d d d d* stay rods, connecting the piston to the frame of the dynamic traveller, the hind wheel only *e* of which can be seen in this view. *f* exhibits an edge view of the bar that connects the dynamic traveller to the governor *g*, of which *h h* are the running wheels, connected by a cranked axletree. In connexion with the vertical arm *f* are inflexible horizontal arms, from which are suspended by pivots or vertical axles, anti-friction wheels *i i*, whose peripheries roll on the outer sides of the longitudinal chase, and keep the vertical arm in the centre, so as to prevent its touching on either

side. This figure also shows the shape of the longitudinal chase or aperture, through which the connexion is made from the interior to the exterior; this chase is cast with the cylinders, and is necessarily continued the whole length of the tunnel. In order that the running wheels of the governor, as well as those of the train of carriages that follow it, may be kept truly upon the centre line of the projecting rails, and never rub against the sides of the tunnel, metallic arms are projected from their frames, carrying anti-friction wheels, the peripheries of which roll against the outer sides of the longitudinal chase and underneath the flange: this latter circumstance affords a great security against upsetting. And for the purpose of keeping the peripheries of these anti-friction wheels always in contact with the chase, whatever curves may be made in the line of railway, their axles turn in slots, and are pressed inward by springs. Into the trough, an elastic flexible padded chain, called by the patentee, the valvular cord, is fitted the whole length of the tunnel, forming, as it were, a continuous valve. In the annexed figure, this valve is shown in section on a greater scale, with

Fig. 4.



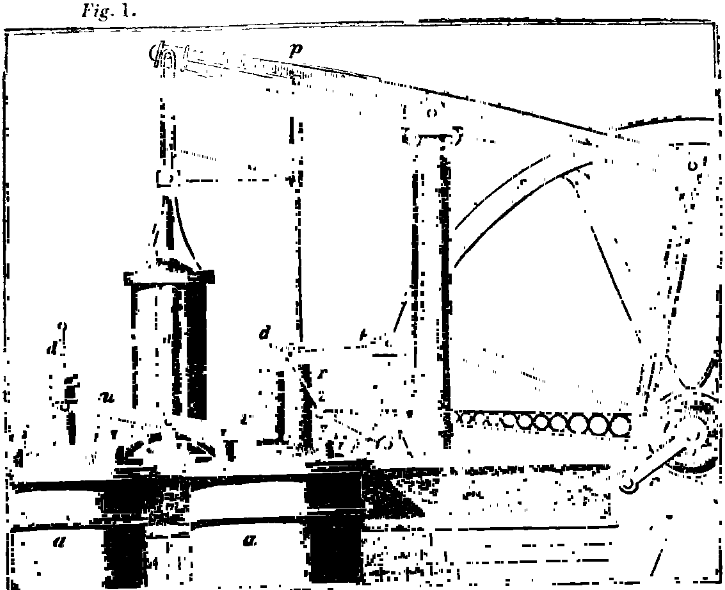
the flexible cord *l* in its place. The sides of this cord, when not compressed, have a curved figure, as represented by the dotted lines; it is surrounded with a coat of felt, and on the top is attached a jointed band *m* of iron, resembling a continuous series of hinge-flaps, the joints admitting of the utmost pliability to the cord, and affording a compensation for the expansion or contraction of the metallic portion of the band; the other materials of the valvular cord are of too soft and yielding a nature to require any provision against the changes of temperature, and these are smeared over, or saturated with, unctuous matter, to keep them soft and more effectually air-tight. By reference to *Fig.* 2 it will be seen that the piston precedes the dynamic traveller in the tunnel; and by reference to *Fig.* 1 it will be perceived that there is a small wheel in the centre, (shewn also at *k*, *Fig.* 3,) with the valvular cord *l* passing over its periphery, while there is another similar wheel in front, and a third at the hind part, which constantly keeps the valvular cord in its trough. The office of the centre wheel is, therefore, simply to keep continually lifting out the valvular cord from its seat, and thereby expose the back of the piston to the full and direct action of the proximate atmosphere; the fore wheel, by its pressure upon the valvular cord, preserving the partial vacuum effected before the piston, and the hind wheel, by its pressure, restoring the valvular cord to its previous station. To enable the conductor to retard or stop the progress of the vehicle at pleasure, the patentee proposes to form a valve in the lower quadrant of the piston, to be opened or closed at pleasure by means of a lever, or a chain and pulleys. With a view to facilitate the operation of transit, and enable various parts of the same line of the pneumatic tunnel to be used simultaneously, the patentee proposes to divide it into sections, (of convenient lengths, which may be determined by the stations of the operating engines,) by intercepting station valves, which may be made similar in form and construction to the common gas valves usually applied to mains; and the connexion may, in this case also, be similar. The patentee, however, prefers station valves of the nature of vertically sliding shutters, running down into sills below the line of the tunnel, as these admit of readier working than the gas main valves. Stationary exhausting engines, or air-pumps, are to be put in action by attached local steam engines, or other convenient first mover; communications between the exhausting engine and the pneumatic tunnel to be made by means of lateral tubes; and the connexions

are to be made in the common manner upon the lower side, at the distance of about 200 feet from the station valve, and on the side of it that lies nearest to the station whence the governor, with its train of carriages, is to be drawn. The stations for the engines may be at 3, 4, or 5 miles apart, according to the power of the engines, the capacity of the pneumatic tunnel, the degree of rarefaction necessary, the average weight to be conveyed, the velocity required, and the height of any inclined plane to be surmounted. As the power to be produced is by the pressure of the atmosphere acting against the piston, in advance of the dynamic traveller, by the rarefaction within the tube before it, the pressure will depend upon the degree of rarefaction; and that may be constantly ascertained by means of barometers placed at the different stations, which will indicate the approach of the governor and its train, and about its distance from the station. A barometer placed on the governor, and communicating by a small tube with the interior of the pneumatic cylinder, and through the piston to its vacuum side, will likewise indicate the degree of rarefaction, and, consequently, the pressure upon the piston, the sufficiency of power to propel, and the time for moving off. Action being given to the exhausting engines connected with the section of the tube through which propulsion is to be effected, the station valve being closed, and the air abstracted from that end of the section of the pneumatic cylinder, rarefaction will take place throughout the whole of the included atmosphere contained in the space lying between the station valve and the piston, which is attached to the dynamic traveller. The partial vacuum thus effected at the station will cause the included column of air to move rapidly towards it; and the incumbent atmosphere pressing upon the valvular cord, will tend to aid the action of the weight of the cord in making the pneumatic valve sufficiently close to prevent the ingress of the external air, and preserve the required degree of rarefaction on the vacuum side of the piston. The unincluded atmosphere rushing into the cylinder through the aperture in the pneumatic valve over the dynamic traveller, (which is laid open by the lifting of the valvular cord over the central wheel of the governor, as before mentioned,) and impinging on the plenum side of the piston, will produce a pressure proportional to the degree of rarefaction on its opposite side, and consequently draw the train of carriages connected thereto after it. On the near approach of a train to a station valve, the latter will be quickly let down into its recess, to allow the former to pass. The valve may then be again raised; and the same engine continuing to abstract the air, as before, from the same section of the railway, it will be again soon prepared for another train in like manner; while the train that had passed into the next section is being operated upon in like manner by the engine belonging to it, and so on, from one section to the other, throughout the whole line of railway. For further remarks on this interesting proposition, we must refer the reader to the article RAILWAY.

AIR MOTIVE-ENGINES. It has been already explained that air expands, or has its elastic pressure increased by the application of heat, and that its volume contracts, and its pressure becomes less, by a decrease of temperature; and several attempts have been made by taking advantage of this property of air, to substitute it for steam, as a prime mover of machinery. Could this be effected, it would be a great advantage in many situations; as, for instance, where water is scarce, or in steam vessels or locomotive engines, where (the machinery forming a part of the load,) it is desirable to reduce the weight as much as possible. Having said thus much of the principle of these machines, we shall proceed to describe one or two of [illegible] for the purpose.

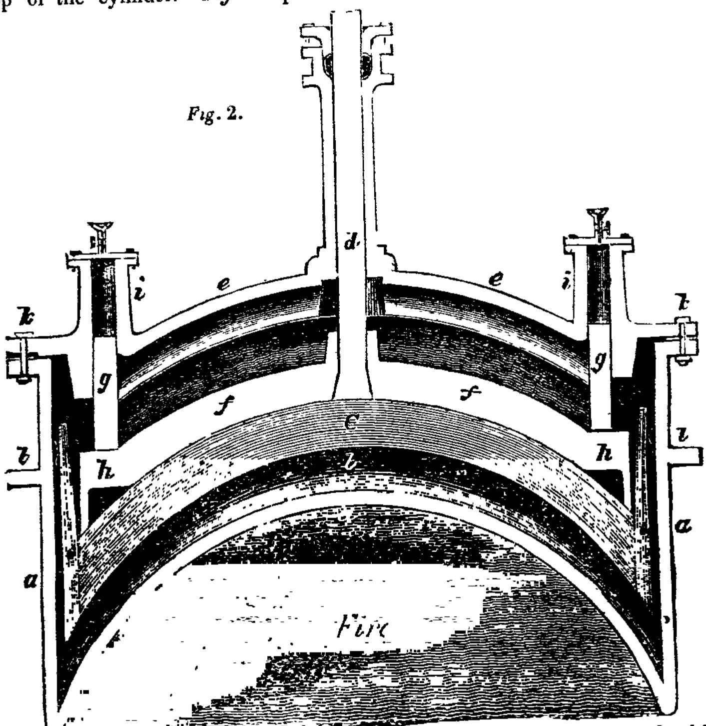
The first we shall notice is Messrs. [illegible] ngine, for which those gentlemen obtained a patent in 18[illegible]. [illegible] nbles the steam-engine in the construction and application of many of its parts, such as the piston and cylinder, reciprocating beam and parallel motion, crank, and fly-wheel, as shewn in *Fig.* 1. Motion is communicated to the piston in the cylinder by alternately heating a portion of air connected with one side of the piston, and at the same time cooling that in connexion with the other. This is effected by means of the air vessels *a a*, one of which communicates with the upper part, and the other with the lower part of the cylinder, through curved nozzles,

Fig. 1.



the pipe *n* forming the communication between one of the nozzles and the top of the cylinder. *Fig.* 2 represents a section of one of the air vessels

Fig. 2.



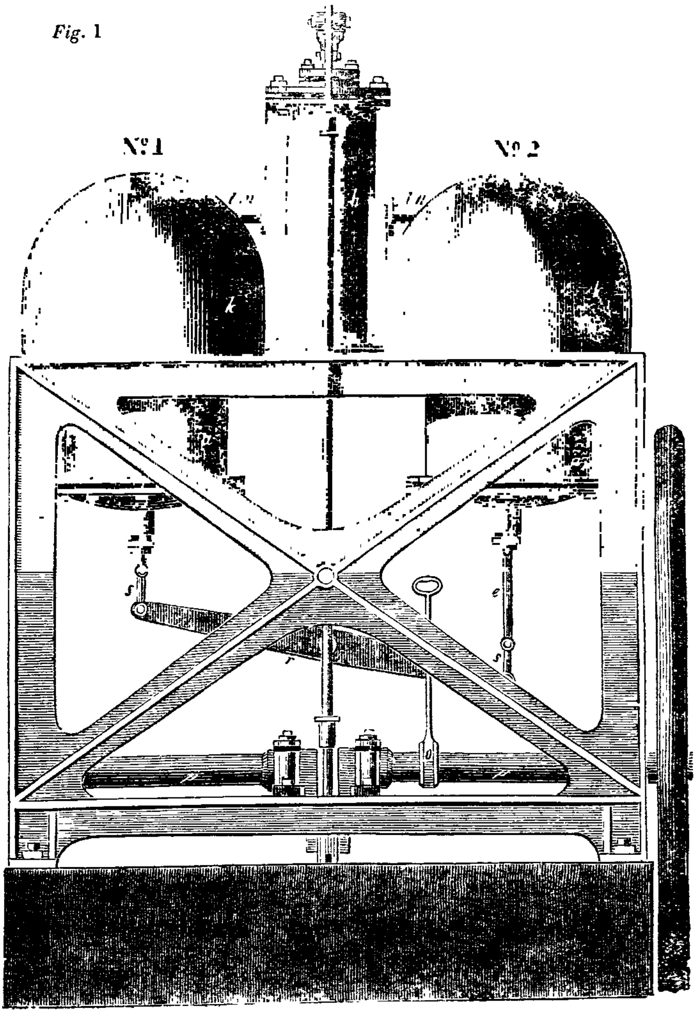
whose sides are cylindrical, and top and bottom spherical. This air vessel, which is made of cast-iron, and supported in the brick-work by the projecting ledge

l l, is furnished with a plunger *c C c*. The top and bottom of the plunger is made of strong sheet-iron, perforated with very numerous small holes to admit the air. The interior of the plunger is filled with very thin plates of sheet-iron, so bent as to prevent their flat surfaces from coming in contact, that the air may have a free passage between them. These are also perforated with small holes, which holes are not placed opposite to each other, but so arranged as to cause the air to pass through the plunger in a zig-zag direction. The plunger is formed circular, to fit the top and bottom of the air vessel when drawn up and down. The rim *c c* of the plunger, which moves in a cylindrical receptacle at the circumference of the air vessel, as represented, is not perforated as the other part. It is kept steady by a spring at *l l*, consisting of a belt of thin sheet-iron, attached at its upper edge to the rim *c c*; a number of slits are made at the lower edge of the belt, to admit of its being bent outwards to rest against the air vessel, and act as a spring. The plunger is also kept steady, in its ascent and descent, by the plunger rod *d* passing through the stuffing-box at the top of its case, and by the guide-rods *g g*, which work in the guide cases *i i*, *Figs.* 1 and 2. The guides are fixed to a ring *h h* which is attached to the plunger and the plunger rod by the arms *f f*, four in number. The guides are supplied with oil by the oil-cup and stop-cock at the top of their cases. The top *e e* of the air vessel is flanged down in the manner represented at *k*, with a thin ring of sheet lead between the flanges, to keep the joining air tight. The lower part of the air vessel is heated by a fire placed under it, and its upper part kept cool by a current of cold air, by water, or by other means. The plunger rods of the air vessels *a a Fig.* 1, are attached by slings to the end of the beam *v*, so that the motion which elevates one plunger in one of the vessels, depresses that in the other. When the plunger is raised, the cold air in the upper part of the vessel will be heated in passing through the interstices of the plunger in its ascent, which has itself been heated on reaching the hot or lower part of the air vessel; and during this time the air in the other vessel will be cooled by passing through the interstices of the plunger in its descent, which has itself been cooled by reaching the cold or upper part of the air vessel. These changes of temperature are further augmented by portions of the air being alternately changed from the hot to the cold and from the cold to the hot parts of the vessels, by the alternate occupation of the hot and cold parts by the plunger. Now, as one of the air vessels is connected with the top and the other with the bottom of the working cylinder, there will be a motion produced on the piston by the alternate application of the expansive force of heated air: and this motion is communicated to the beam *v* through the piston rod and parallel motion, and joins the beam to the fly-wheel *s s*. On the axis of the fly-wheel is fixed an eccentric *t*, which communicates motion to the plungers in the air vessels through the system of levers 1, 2, 3, 4, and the beam *v*, and this motion is adjusted so that the change of the plungers shall be effected whenever the piston reaches the top or bottom of the cylinder; thus applying to that end of the cylinder where the piston is, the hot air, which, by its increased elasticity, will drive the piston to the other end. This engine is also furnished with an air-pump, the piston rod of which is shown at *x*, for condensing the air into the reservoir *w w*. The air is permitted to pass through self-acting valves into the curved nozzles, and thence into the cylinder, or the air vessels *a a*, but is not permitted to return from these vessels or the cylinder into the reservoir *w w*; which is also provided with a safety valve for the escape of superfluous air, when more is pumped in than is necessary to supply the air vessels. The air-pump is only occasionally required to be set to work.

In 1828, Messrs. Parkinson and Crossley took out a patent for an air-engine, which differs considerably in the arrangement of its parts from the one just described; and as it appears to be of a somewhat simpler construction, we shall lay a description of it before our readers. *Fig.* 1 shews a front elevation of so much of the engine as is necessary to explain the invention. *Fig.* 2 is an end elevation, and *Fig.* 3 a section (upon an enlarged scale) of a differential vessel and its transferrer, exhibiting also a mode of heating and cooling the differential vessel. The same letters in each figure where they occur, refer to the same parts. The differential vessel *a a* is of the form of a hollow cylinder with convex ends,

of such a length as to preserve an essential difference of temperature between one end and the other, and nearly one-half being exposed to a hot, and the other half to a cold, medium. The vessel has a stuffing-box at the end *f*, and at the other end is an opening or pipe *l m* or *l n*, for the purpose of forming a com-

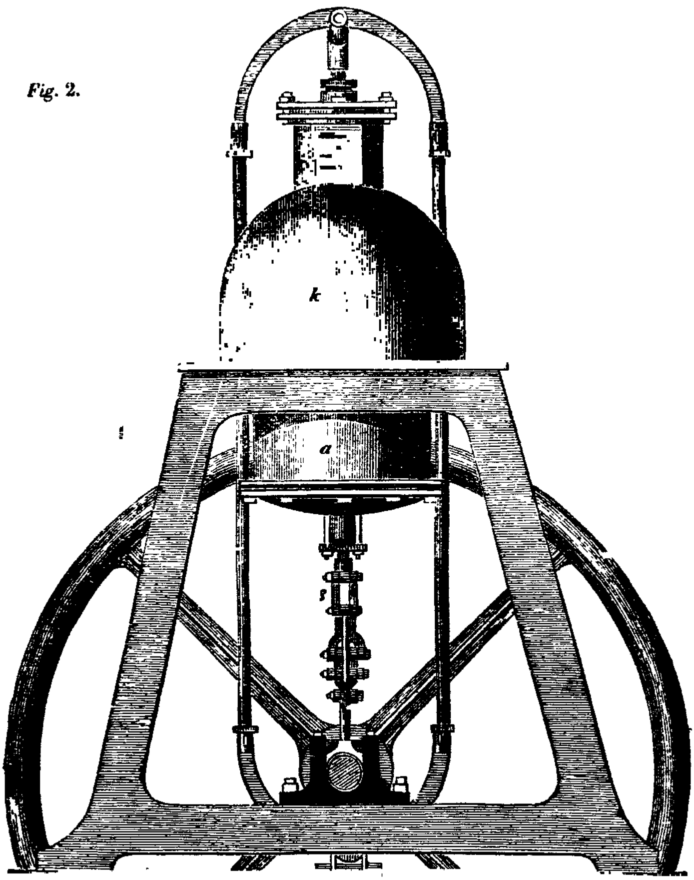
Fig. 1



munication with the working cylinder and piston. The transferrer *b b* is a hollow vessel, air tight, and so much shorter, as to leave a sufficient space in the differential vessel for containing a volume of air, which, when expanded by heat passing through the pipes *l m* or *l n*, will also fill the working cylinder, and force the piston from one end of it to the other. The transferrer is also made only so much less in diameter than the differential vessel as to allow it to move freely from one end of the differential vessel to the other. To one end of the transferrer is fixed a rod *e*, passing through a stuffing-box *f*, for the purpose of moving it from one end of the differential vessel to the other, thereby causing the air to pass in a thin stratum against its hot and cold parts alternately thus producing

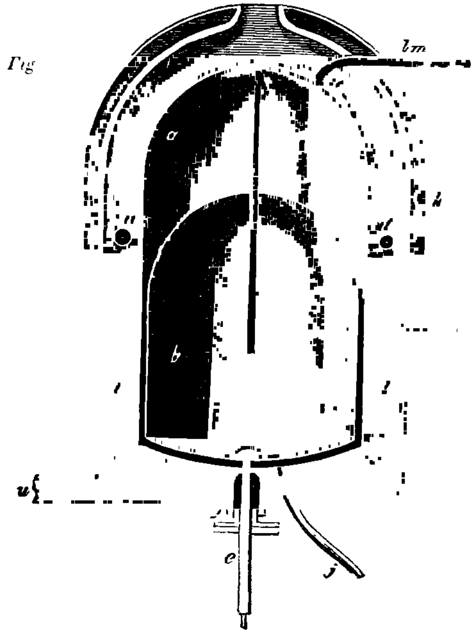
the force or power to be employed against the working piston. The rod *g*, *Fig.* 3 which is fixed on the upper part of the differential vessel, is intended to guide the transferrer in its proper direction, by means of a tube which is inserted in the upper end of the transferrer, the lower end of the tube being made air-tight. Motion is given to the transferrer by means of the eccentric *o* in the

Fig. 2.



shaft *p* being connected with the beam *r*, which beam is connected to the rod *e* of the transferrers by the links *s s*. The working cylinder *u* with its piston, side rods, cranks, shafts, fly-wheel, and eccentric motion, are the same as those commonly used in steam-engines, and therefore require no particular description. The pipe *l m* forms a communication between the differential vessel, No. 1, and the top of the cylinder; and the pipe *l n* connects the differential vessel, No. 2, with the bottom of the cylinder. The operation of the engine will be as follows: Supposing the eccentric disconnected from the beam *r*, and the upper part of the differential vessels heated, and their lower parts cold, and the transferrers of

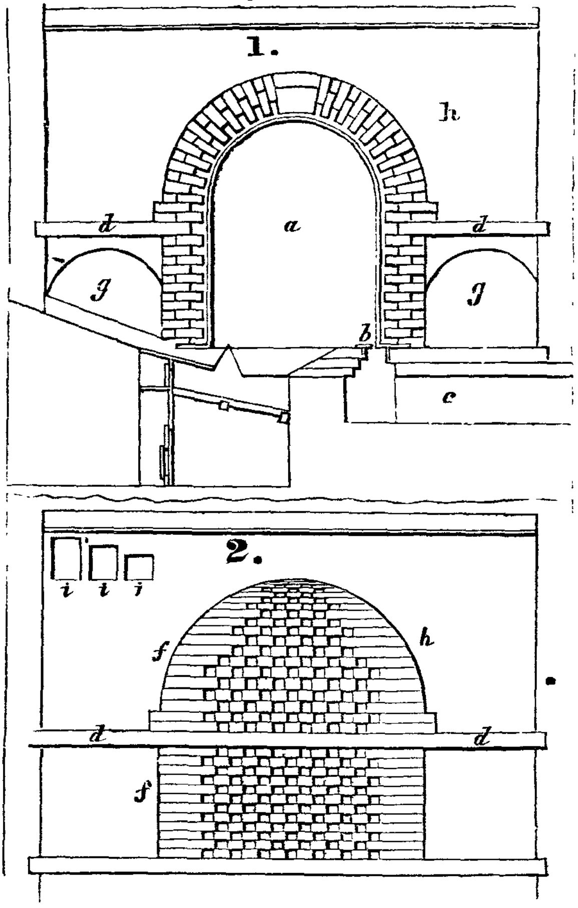
the two differential vessels placed by hand in the situations shown in the figure, and the volume of air occupying the hot part of the differential vessel, No. 2, and being increased in elasticity in proportion to its temperature, whilst the volume of air in the differential vessel, No. 1, is occupying the coldest part, the working piston will be forced upwards by a power corresponding with the dif-



ference of the elastic force of the air in the two differential vessels; and when the working piston has been forced to the top, the situation of the transferrers should be reversed by hand, so that the air in the differential vessel, No. 1, will occupy the hot part, and communicate its force to the upper side of the working piston, and thereby produce a returning stroke; and the eccentric being then by hand re-connected with the beams, the alternate expansion and contraction of the air in the two differential vessels will keep the engine in motion; and then, by working the transferrer in the same way as the valves in steam-engines, the engine may be either stopped or put in motion. For the purpose of heating the differential vessels, the inventors prefer the employment of inflammable gas, a mode of applying which is shewn at *Fig.* 3, where *d d* is a hollow ring, surrounding the differential vessel, and communicating with the tube by which the gas is supplied; this ring is perforated for the emission of jets of gas, to flow, when ignited, all round and against the differential vessel, or nearly so; *c c* is an iron vessel, for directing the heat to the differential vessel, which casing is open at bottom for the admission of air, having also an opening at top, to serve as a chimney or flue; *k* is an outer covering of polished metal, of about two or three more inches in diameter than the casing *c c*, for the purpose of lessening the radiation of heat. The working cylinder *h* may be kept hot by means of a current of heated air being conducted to it from the flues of the differential vessels. *t t* represent the differential vessel placed in a cistern of cold water, with a constant current running in at the bottom *u* against the differential vessel, and passing off at the top *v*. We are not aware that the engine just described has been brought into practical operation, but that invented by Mr. Stirling was employed in a stone quarry; it has, however, we learn, been replaced by a steam-engine, in consequence of its inferiority to the latter in the economy of

working, particularly as respects the consumption of fuel. One objection to air-engines is, that the changes of volume do not take place with sufficient rapidity, and that when water is employed to accelerate such changes, the quantity necessary for that purpose is greater than would be required to supply the boiler of a high-pressure steam-engine; so that in situations where either water is scarce, or the weight of it an objection, the latter engines would, on those accounts, be found superior to the former.

AIR STOVE. A stove, the heat of which is employed to heat a stream of air directed against its surface, which air is then admitted to the apartments requiring to be heated. The principle of the construction is, to inclose the stove containing the fuel in a casing somewhat larger than the stove, so as to leave a space of a few inches between them. At the lower part of the casing is an aperture filled with a register to regulate the admission of the air, and at the



upper part is a similar opening to allow of its exit. When the air-stove is not fixed in the apartment which is to be heated, a pipe is fitted to the upper aperture of the casing, to convey the air to the apartment. The construction may be varied to suit circumstances; the above cut is a representation of one which has been used with very good effect to heat the Infirmary at Derby. It is upon a plan which was first introduced in this country by Mr. Strutt, of Derbyshire, who employed it for the purpose of warming his extensive cotton works more

uniformly and with greater economy than formerly. *Fig.* 1 is a section of the air-stove and cockle; and *Fig.* 2 a transverse section of the stove, exhibiting the disposition of the masonry surrounding the cockle. *a*, the cockle, is made of a cubical form, with a dome, or rather a groined arch top, about 3 or 4 feet high, and is made of plate or wrought iron about $\frac{3}{16}$ of an inch thick, riveted together like the ordinary boilers of steam-engines. The smoke passes off by a narrow passage at *b*, at the base of the cockle into the flue *c*, which leads to the chimney. The brick-work surrounding the cockle is built with alternate openings, as represented in the side view at *f*, at about 8 inches distant from the sides of the cockle. Through these apertures pipes are inserted which may be made either of sheet-iron or of common earthenware, so as to extend within an inch of the cockle, by which means the air to be heated may be thrown near, or in immediate contact, with the surface of the cockle if desirable, which was found by Mr. Strutt to double the effect derivable from the same quantity of fuel. The horizontal partition of the air chamber at *d* cuts off the communication between the lower and the upper half of the chamber. The arched openings in the lower half *g g* exhibit the openings of the main air flues leading from the exterior atmosphere. The air passing from these lower flues *g* through the apertures beneath the horizontal partition *d d*, and coming in immediate contact with the body of the stove, must find its way into the upper air chamber *h*, through the numerous apertures or pipes in the upper division, by which circuit its velocity will be retarded sufficiently to obtain the necessary elevation of temperature from the heated cockle. In order that the air may not be injured for the purposes of respiration, the size of these Belper stoves, as they are called, must be so regulated as not to heat the cockle or body of the stove at an average above 280° Fahr., or according to Mr. Sylvester, or 250° according to Mr. Tredgold, when the air is intended to supply living rooms; but for drying rooms more heat may be given, if the saving of time is an object; but still it is far more economical to dry at a lower temperature. From the upper, or hot-air chamber *h*, a main flue *i* leads to each of the floors to be heated. The horizontal and inclined parts of these main flues should be made of brick or stone, and if they have to pass under ground, should be secured in a case. The vertical parts may be of sheet iron, or even of well-seasoned wood. An opening over the door of each room allows the entrance of the heated air into it, and a flue from the bottom of each room proceeds to the roof of the building, from whence the whole of the air is discharged by a turncap, the mouth of which is kept constantly from the wind by a vane. Provided a stove of this construction is well built, and so managed as not to allow the heated air to attain too great a temperature, it is not only much more economical than any other mode of warming extensive buildings, but it is equally salubrious with the more recent method of employing steam pipes for this purpose, if not more so. As the air passages of this kind of stove ought to be several feet under ground, it affords also a convenient mode of admitting a portion of cold air to the interior of the building in the summer season, as well as supplying heated air in the winter. The change in the temperature of the air by passing in this way, Mr. Sylvester says, is greater than could be supposed. The cold air flue at the Derby Infirmary is about 4 feet square, and its length 70 yards. In the month of August, when the thermometer in the shade stood at 80°, the air which entered the air flue underground at the same temperature, was found to be 60° at the extremity where it entered the stove-room; the current at this time was sufficient to blow out a lighted candle. In another experiment, when the outer air was 54°, this air was reduced to 51° by passing through the flue. This is a great advantage of the air stove above the use of the steam apparatus, since this last only supplies the deficiency of heat in winter, but has no tendency to check it when the temperature of the atmosphere is beyond the mean temperature of the earth. But although close stoves, and air stoves in particular, are decidedly more effective and economical than open fire places, still the prejudice is so strong in England in favour of the latter, from their more cheerful appearance, and their freedom from any unpleasant and confined smell which is apt to arise from stoves when they become highly heated, that there seems but little chance of the latter

superseding the former. It is therefore desirable, if possible, to derive from an open fire-place a portion of the advantages of an air stove, and accordingly, many combinations with that object have been devised. The following one is by Mr. Ricketts, of the Strand; besides the grate, it comprises an oven, boiler, and hot air chamber, all heated by one fire, without flues. No. 1 represents the range, as fixed; No. 2, the hot air chamber distinct; No. 3, a vertical elevation

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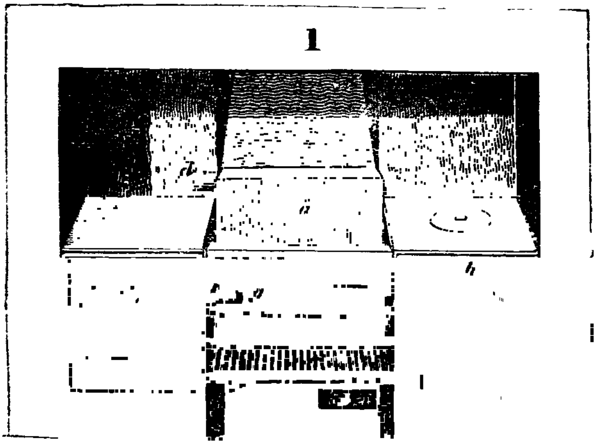

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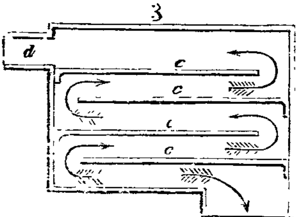

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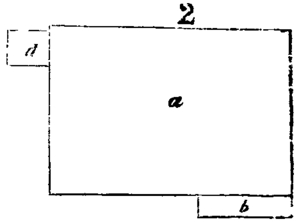
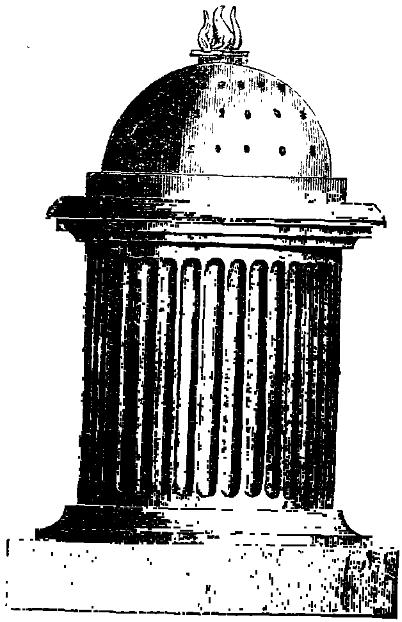
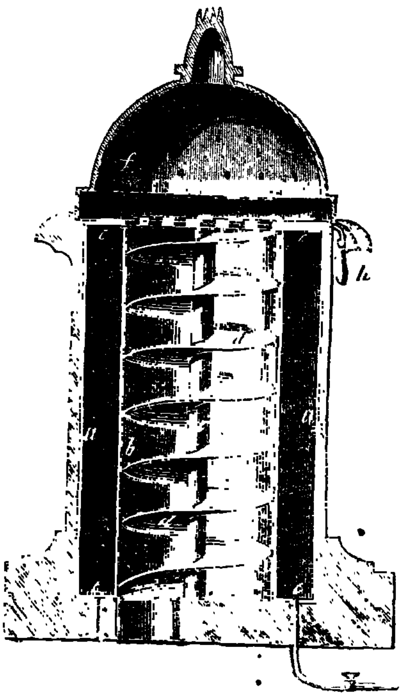


of the same chamber: the same letters in each figure refer to similar parts. *a* the hot-air chamber; *b* cold-air drain, or aperture, at bottom of the chamber; *c* thin iron plates or ribs 2½ inches wide, to direct the passage of the air against the heated back of the chamber, producing a current of hot air which may be communicated by pipes to any part of the building; *f* conducting oven, heated by an iron knob *g*; *h* an iron boiler to which the steamers may be applied.

It has been mentioned, that stoves are liable to the objection of sometimes causing an unpleasant sensation from the air becoming over-heated, or, as it is termed, burnt. This may be obviated by heating the air destined to circulate in the apartments by steam, instead of employing the direct action of the fire. An apparatus of this description, patented by Mr. Stratton, is shewn in the following figures. *Fig.* 1 is an elevation, and *Fig.* 2 a section of the apparatus. It consists of an exterior tube of copper *a*, *Fig.* 2, within which is a smaller tube *b* of equal length, soldered to end plates *c c*, forming thereby a steam-tight vessel, surrounding the interior tube *b*. *d d* is a spiral apparatus of copper, coiling round the upright rod *e*; the periphery of this spiral exactly fits the interior tube *b*, so that no air can pass up or down without taking a winding course through the spaces formed by the spiral. *f* is a semi-globe of copper, perforated with holes; and *g g* are two moveable plates, in which are cut oblong apertures, so that when the holes in each coincide, the air has a free passage through them; but when they are moved by the lever *h*, so that the holes in one are covered by those in the other, the passage is stopped, and the

air ceases to flow. *i* is a steam pipe, for the purpose of admitting steam from a small boiler; and *j* is another pipe, for allowing the water formed by condensation to run back into the boiler or elsewhere. Steam being admitted into the compartment formed between the two tubes by turning the cock, instantly heats the interior tube *b*, and (by radiation) the spiral *d d*, by which the air already filling the tube is expanded, and rises by its diminished gravity, escaping into the open atmosphere through the holes in the cap *f*. The air underneath rushes in to fill the partial vacuum, and in its turn becomes heated; by this means a constant current can be kept up so long as the compartment is supplied with steam; but this current would, in an unimpeded passage, be much too rapid in its motion to become sufficiently heated for the purpose intended. The spiral *d d* is therefore introduced, which causes the air (as we have said) to take a winding course, and thus traverse the whole heated surface of the spiral before its exit into the air. By this contrivance the air is made to traverse over a considerable surface of heated material, while the steam required to act therein is confined to a very short vessel, and, consequently, has but a small portion of its surface exposed uselessly. It may be cased in wood or other non-conducting material, if desired, for ornament or any other reason, without any diminution of its effect in warming the apartment.





The following simple and ingenious air stove is the invention of Mr. Perkins, of Fleet-street, and the engraving represents a stove upon his plan, which was put up on the premises of Messrs. Coe and Moore, printers, Old Change. *Fig.* 1 represents the stove, flue, and building, in which it is fixed. *Fig.* 2, a continuation of *Fig.* 1, on a smaller scale, extending it above the roof of the building. The letters of reference designate similar parts in each

figure. The stove *a* is of a cylindrical form, fixed vertically in the brickwork it is closed above by the lid *b*, which is removed as often as may be required to supply the stove with fuel (coke is preferred). *c c* is the flue, which is a tube of wrought iron, excepting that curved portion immediately connected to the furnace cylinder, which is of cast iron. *d* is the ash pit. At *i* is an elliptical aperture, for the supply of air to the fire, which may be admitted in a greater or smaller volume by wholly or partially removing the cover *k*. *l* is a furnace door, for affording convenient means for clearing out the ashes. The grating on which the fuel is laid, is not fixed, as usual, immovably in the brickwork, but is connected to the frame by hinges on one side, and held up on the other by a cross-bar, which rests on a button *m*. This button being turned one quarter round, the grating immediately falls as a trap door, discharging all the fuel into the ash-pit, by which the fire is almost immediately extinguished without trouble. The stove is placed on the floor of the basement or cellar, which is kept thoroughly warm and dry, so as make it a good store room for paper, although it is under ground; from thence the flue ascends through the ground floor *n*, the first floor *o*, the next floor *p*, and passes through the roof, as shewn. The flue for the smoke *c c c* is surrounded, as shewn, by a larger tube, at about 3 inches apart, for the conveyance of heated air to the several apartments. To effect this, cold air is freely admitted through a large aperture *r* in the wall, which enters the chamber *s*, and impinging upon a strongly heated surface, it immediately acquires a much higher temperature. To increase this effect, the curved cast-iron neck of the flue adjoining the stove is considerably flattened or expanded, so as to expose to the ascending column of air a more extended surface of heated metal. The caloric given out by the burning fuel, instead of being chiefly carried off by the flue, as in ordinary stoves, is rapidly abstracted by the current of air, which air, thus heated, may be wholly or partially given out into any one apartment, or distributed in the several apartments, as may be desired (either for drying the printed sheets, or for warming the persons at work,) by a few simple valves or registers. These registers are made of two separate annular plates, sliding circularly on their flat surfaces one over the other. The lower

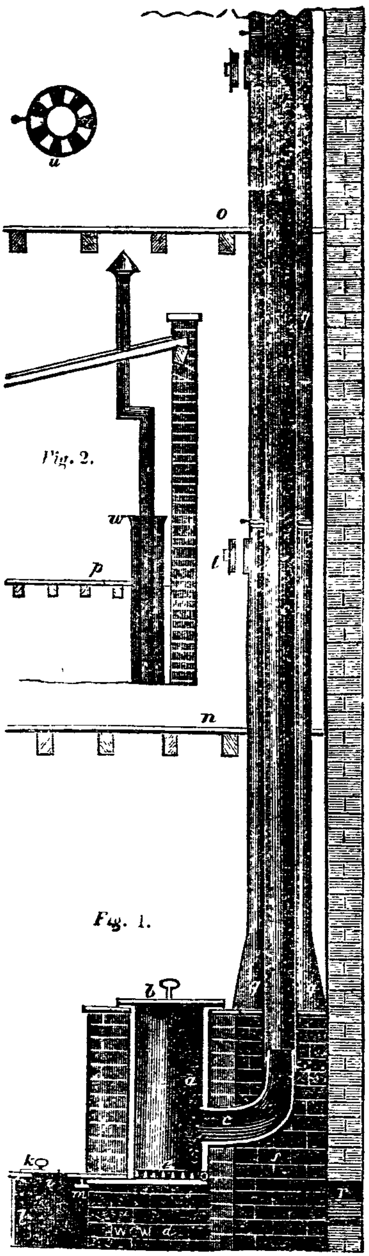
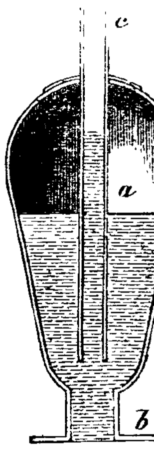


Fig. 2.
Fig. 1.

one is fixed by rivets to the sides of the external tube, and the upper one lies on the lower one, and is made to slide over it by moving to the right or left a small handle, which projects horizontally through a slot mortice in the external tube. The size of the interstices in these plates is both alike, as shewn in the separate *Fig. u.* By these registers, it will be seen that the whole of the hot air may be confined to one apartment, or distributed over several. The apertures through which the heated air flows into the rooms, are 10 or 12 inches in diameter, and each one is provided with a cover like a saucepan-lid *t*, to prevent, at pleasure, the hot air from entering any particular chamber. In the uppermost floor the flue of the hot-air tube terminates at *w*, about 3 feet above the floor; from thence the smoke flue alone ascends, which first rises a few feet, then takes a horizontal course, and afterwards passing through the roof, the upper extremity is provided with a canopy or cowl to keep out the rain, and to prevent the smoke from being forced downwards by sudden gusts of wind. The premises before mentioned are thoroughly warmed throughout the winter, at as high a temperature as is consistent with the comfort of the persons employed therein, at an expense of less than nine pence per day for fuel. But one of the chief advantages that result from this apparatus, is the convenient and facile manner by which the heat can be augmented to the required degree in any apartment, for the purpose of quickly drying the freshly printed sheets of paper, an advantage evidently of the first importance to printers, as it enables them to print their work with extraordinary despatch. But when a stove of this kind is not employed for drying moist substances, the hot air should be first brought into contact with a vessel of water, to render the air sufficiently humid for healthful respiration.

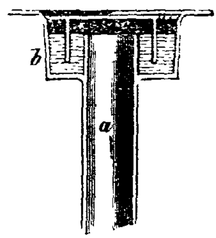
AIR BEDS. A bag of the size of a bed, divided into several compartments, and rendered air-tight by a composition, of which caoutchouc, or Indian-rubber, forms the greatest part. This bag may be inflated by bellows, a syringe, or any other means, and is furnished with stop-cocks to retain the air or let it out at pleasure. These beds will be found extremely convenient to travellers, especially in warm climates, from their portability, and not being liable to vermin; also to invalids, from their perfect elasticity, which may be regulated at pleasure by an attendant, without disturbing the occupant.

AIR VESSEL, IN HYDRAULICS, a contrivance to continue the flowing of water after the impelling force has ceased to act, as in the return stroke of a forcing-pump, or in Bramah's hydrostatic press, thus preventing the shocks which would arise from the sudden stoppage of the water whilst in motion, and also avoiding the loss of power in moving it from a state of rest at each effective stroke. It consists of a vessel containing air, which is placed between the delivery valve and the mouth of the delivery pipe, and the water being forced through the pipe faster than it can escape at the orifice, rises in the air vessel, compressing the air therein with a pressure proportionate to the pressure on the delivery valve. On the return stroke, when the piston ceases to act, the air expands and continues the flow of water until the pressure of the air is only equal to the pressure of the column of water between the air vessel and the mouth of the delivery pipe. See the cut, in which *a* is the air vessel; *b* a flange by which it is attached to the delivery pipe or main; and *c* the exit pipe.



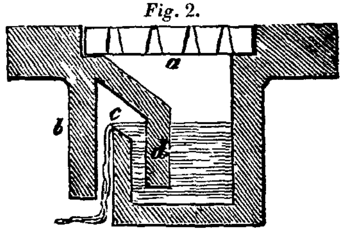
AIR TRAP. A contrivance for excluding the effluvia arising from drains, &c. The most simple and effectual trap for this purpose consists of what is termed a water joint, which may be variously arranged. *Fig.* 1 represents the construction commonly adopted for sinks in kitchens, &c. *a* is the pipe leading to the drain, the upper end passing through the bottom of a small metal cup *b*, the rim of which rises somewhat higher than the top of the pipe, and is cemented or soldered into the sink. Over the mouth of the pipe is inverted a cup

Fig. 1



c somewhat smaller than the other, and descending to within a short distance of the bottom of b, and on the top of this is fixed a strainer to prevent the passage of substances which would choke the pipe. Now as the water in passing off by the pipe will always leave the cup b full up to the top of the pipe, the cup c will always be immersed to a certain depth in the water, which will effectually prevent the escape of foul air from the pipe a, for air being lighter than water, cannot of course descend through it. *Fig* 2 represents an air trap, which, instead of being made of metal, is fabricated of the common red pottery, and is particularly adapted for falling into a course of the "flooring quarries," used in many parts of the country, which are cleansed by washing and sluicing them with water. In its superfices it presents a square of 9 inches, the same as the ordinary quarries. *a* is the grating; *b* the trap frame. It will be evident no foul air can pass up the grating, as the only passage for it is through the water, over the stop *c*, and under *d*.

Fig. 2.



AIR PIPES. An invention of Mr. Sutton, a brewer, of London, for ventilating the holds of ships, and for drawing out the foul air which arises from the bilge water, and collects between the timbers. A pipe proceeding from the lower part of the hold is brought up to the ash-pit of the ship's coppers or other fire-place, and the air becoming rarefied by the fire above it, it ascends, and its place is supplied by the external air rushing into the hold through the interstices between the timbers, or by pipes descending for that purpose from the deck to the hold.

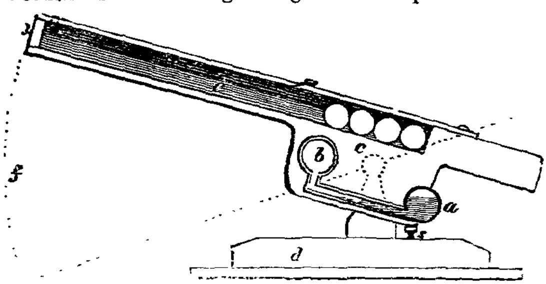
AJUTAGE. The tube or mouth through which water is discharged. On the forms of these depend in a great degree the force and velocity of the motion of the fluid. See HYDRODYNAMICS.

ALARM, OR ALARUM, is a term applied to a variety of instruments constructed for the purpose of producing sufficient sound or noise to awaken a person from sleep, or otherwise to give notice of some occurrence, or warning, of the state of the time, &c.

Glenny and Darby's Fire and Burglary Alarm. The object of this invention, for which a patent was taken out in 1820, is to indicate by means of a placard or signal, containing the written information, in what part or situation of the premises to which it is attached, a fire or burglary has taken place, immediately upon either having happened. This is effected by placing an alarm-bell within a box, (having the appearance of any article of furniture,) the internal mechanism of which is connected by lines or wires to every part of the premises deemed to be hazardous. These lines, carried from the alarum in the manner of bell-wires, are at their extremities connected to triggers, any one of which being discharged, releases its line immediately, and sets off the alarm-bell within the box, firing a pistol also, if attached thereto; and at the same time, causes a slider or label to be presented, containing the words, "Fire," or "Thieves," in such a part of the premises, describing where, and which of the two occurrences. The construction of the apparatus is as follows: A box of any external appearance, placed in the bed-room or elsewhere as a piece of furniture, contains the alarm-bell, which is connected to the striking part of a clock. Each of the lines before described, are connected at one end to a piece of metal as a trigger, which is hooked to a hold-fast, placed in such a situation that, by the opening of a door or window, the trigger is liberated, and the line which passes over the pulleys placed at every angle, is drawn back by the other end being attached to a weight inside the box; the weight in descending strikes against a lever formed by a projecting pin, fixed to, and turning on, an hori-

zontal axis. This axis carries a series of lever pins, corresponding with the number of lines, weights, &c. employed; so that any one of the weights by falling, causes the axis to turn, and by means of an arm projecting from the axis, a wire connected to the striking part is pulled, and the alarm set off. The labels or slides before mentioned are each connected by a line or chain to its respective weight, which, on its descent, projects or draws out to view the label conveying the required information. In adapting this apparatus to indicate the occurrence of *fire*, small lines of catgut, or threads of sufficient strength, are substituted for the before mentioned lines, which are carried across the ceilings or round the cornices of the apartments to be guarded. Some one of these slender strings, it is considered, would be soon burnt by the ascent of the flame, and give early notice of the destructive element, by the alarm bell to which it was attached being put in action, which would at the same time indicate the situation of the fire. Prior to the granting of this patent, many of the mechanical arrangements described under it were in use, and the patentee's claim to invention may be considered as limited to the introduction of the direction labels, which, in a large building, might prove of eminent use.

Russell's Fire Alarum. This apparatus is put into operation by the expansion of a small quantity of air contained in an instrument called a pulse glass, which consists of two bulbs, with a small tube of communication between them. Into this vessel is put some liquid, usually coloured, so as to about half fill it, the remaining space being occupied by air; it is hermetically sealed. This instrument is so extremely sensible of a slight increase of temperature, that on placing merely the hand upon one of the bulbs, or by gently breathing upon it, the liquid is rapidly forced out through the tube into the other bulb, owing to the expansion of the air within that bulb to which the warmth is applied, and producing an apparent ebullition in the liquid by the bubbling of the air through it. When these bulbs are equipoised upon an axis placed midway between them, it is obvious that the liquid flowing into either bulb will cause it to preponderate; and to obtain from this preponderating action sufficient force to set off an alarum, Mr. Russell contrived the following arrangement. *a* represents one of the glass



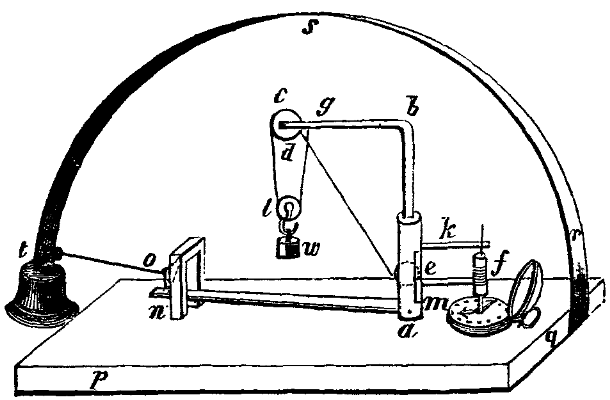
bulbs, nearly filled with the liquid, which should also fill the tube of communication up to the opening into the bulb *b*; the whole of this vessel is enclosed in a cavity cut out of a block of wood, except a portion of *a*, which is exposed for the purpose of being influenced by an increase of temperature. The block turns freely upon a centre or fulcrum at *c*, fixed upright in a stand *d*. *e* is a long mortised lever or tube, containing four leaden balls, so placed over the fulcrum as to rest in equilibrio. Upon heat being applied to the bulb *a*, the air above the liquid rapidly expands, and drives it into *b*; the weight being thus increased on that side, causes the lever to descend in the direction of the line *f*, while at the same instant the leaden balls suddenly roll down the inclined plane, accelerating the descent of the lever, and impart to it a considerable degree of force, which it is evident may be almost indefinitely increased by lengthening the lever, or augmenting the rolling weights. As motion is thus produced, attended with great power, its application to the ringing of a bell, or any number of them, or the firing of a gun, may be easily understood, all that is required being a crank, with a wire connecting it to the alarm used. If a water pipe and stop-

cock were attached to the fulcrum of the lever, the plug of the latter would thereby be opened, and the floor underneath be deluged with water.

Colbert's Fire Alarm. This consists of a column of mercury in a tube, with a floating piston, which ascends and descends as the mercury expands and contracts. A rod from the piston is connected at its upper end to a lever, which, on being raised, releases a click or detent, and discharges the alarm. The apparatus is provided with a dial plate and index, pointing to the degrees of heat, which is to be adjusted to a few degrees of heat above the temperature of the atmosphere, or above the utmost height to which it is expected the mercury might rise from natural causes during the night. It is enclosed in a case of open fret-work, for the purpose of readily transmitting the heat, and is to be deposited in the well of a stair-case, or other desirable place.

Congreve's Fire Alarm. The late Sir William Congreve suggested the employment of two metal plates placed in contact, with a cement between them, that would melt at a low temperature. These plates were to be suspended by a thread to opposite corners of a room, when it was considered that a slight increase of heat would melt the cement, cause the plates to fall asunder, and discharge the alarm. If the reader will refer to the experiments detailed under the article Adhesion, he will find abundant reason to doubt the certainty of the ready separation of the plates under the circumstances mentioned; and he will then probably give the preference to the following suggestion of our own. Provide a common house bell and spring. To that end of the spring by which it is fixed to any object, tie a short piece of tape, sufficient to reach, when extended, only half way to the bell; and to that end of the spring next to the bell tie another piece of tape of the same length as the former. Then compress the spring, so that the tapes can overlap each other, and insert between them a piece of wax, (made of equal parts of common resin and bees' wax) which may be compressed together by the fingers. The overlapping may be to such an extent as will cause the wax to soften and the tapes to separate, on applying a heated atmosphere to them of about 100° Fahr., when the elasticity of the spring will produce the required clattering of the bell.

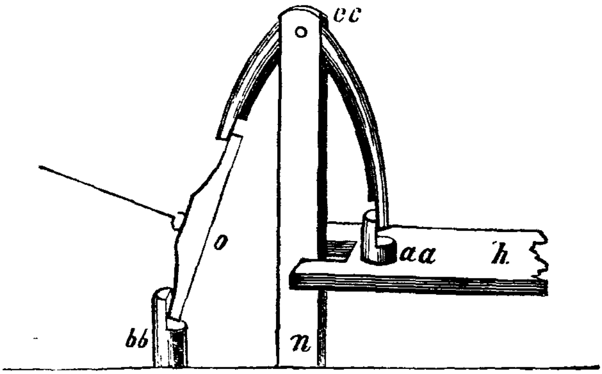
We shall now proceed to give a few examples of alarums for giving notice of the arrival of predetermined periods of time, by means of easily constructed mechanism, referring the reader to Clocks and Watches for those of a more



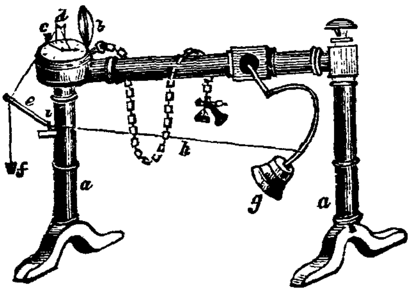
elaborate nature The above figure represents a watch alarum, which the inventor states he has made several of, and that they answer extremely well. In a solid frame of wood p q about 8 inches by 4, and 1 thick, is inserted a metallic rod, bent into a right angle at b, to which are attached a small rod k, and two fixed pulleys d e. f is a cylindrical piece of wood, having inserted at one end the pipe of a watch key, by which it may be made to rest on the pivot of the watch, (the watch being sunk a little into the frame,) and turns with the

minute hand, and at the other, a pin which keeps it steady by passing through a hole in the rod *k*. A thread which is fixed to the piece *f*, and may be rolled round it, passes under the pulley *e* over *d*, and round the moveable pulley *l*, to which the weight *w* is attached; and being brought through a hole in the rod *b c* is fixed there by the pin *g*. This pin is used to regulate the length of the thread so that when it is completely wound off the cylinder *f*, the weight *w* may rest on the plane *h*, which is moveable on a pin at *m*. The bell is fixed to one end of a long spring *r s t*, the other end of which is fastened to the board at *r*; at *t* is fixed a string, which keeps the bell in the position represented in the figure, by means of a bit of wood *o* inserted into two notches, one in the plane *h*, and the other in the horizontal part of the frame *n*; the friction of the bit *o* preventing the plane *h* from falling. It will be easily perceived that by winding the thread a certain number of times round *f*, the weight *w* will be raised to a height from which it will take it so many hours to descend to the plane *h*, and that when it does reach that plane and press upon it, the bit *o* will be released from the notch, and the elasticity of the spring will make the bell ring with considerable violence.

An improved mode of releasing the bell, described in the foregoing plan, is exhibited in the subjoined diagram, wherein the parts are drawn upon a larger



scale. In this figure the bit of wood *o* is supposed to be tightly pulled by the string attached to the spring of the bell, its lower end being detained by a fixed piece *b b*, and its upper end held by a bent piece of brass, which turns upon a centre at *c c*, and whose other end sustains the plane *h* by pressing against the piece *a a*. The descent of the weight depressing the plane *h*, causes the bent piece of brass to swing loose and release the piece of wood which is connected to the bell.



The annexed figure represents a watch alarum that is sold in the shops of London, and which we have seen perform with considerable accuracy. The expense of it is only seven shillings. *a a* is a turned mahogany stand; *b* the watch laid in a velvet cushioned cavity adapted to receive it, and placed in such a position, that the hour at which a person may wish to rise, shall be placed opposite to a fixed index *c*. A fine line, consisting of a single horse hair, with a loop at the end of it, is then laid into the notch of a guide piece *d*, and the loop is then slipped over the hour

hand of the watch. At *e* is a light ivory lever; to this the horse hair is tied about midway of its length, with a weight *f* suspended to its lowest end. The bell *g*, fixed on its steel spring, is then brought into the position shown by the line *h*, the extremity of which line is provided with a brass wire hook, then passed over the extremity of the lever, and put on to the upright pin *i*. When, by the process of time, the hour hand has arrived at the period proposed, which is opposite to the point of the index, the horse hair slips from it, the little weight thereby becomes unsupported, pulls down the ivory lever, raising the hook of the pin, which, releasing the spring, sets the bell ringing.

The periodical journals a few years ago abounded with plans of simple alarums; and any person having a taste for such trifles in mechanics might easily multiply them, as the materials as well as the arrangements of parts may be almost infinitely varied. Sand, passing through a minute perforation, (as in the hour-glass,) and charging a receptacle, whose weight in due time gave motion to a bell, was a common expedient. The substances used for domestic light have also been called into use, to show by their uniform decrease of quantity the time passed, and by their decrease of weight in consequence allow the reaction of a constant force to give motion to an alarum. The most perfect and elegant piece of mechanism for this purpose, is Berrollas's patent watch alarum, which we have fully described under the head HOROLOGY.

ALBUMEN. A viscous ropy fluid, found in its greatest purity in white of eggs, from whence it derives its name. The serum or colourless part of the blood, the crystalline humours of the eye, and all animal matters, contain it in great abundance. It is also found in many vegetables, more particularly in those which undergo spontaneous fermentation. The juice of the papau tree, mushrooms, and many other fungi, contain considerable quantities. Pure albumen may be obtained by agitating the white of an egg with alcohol, which separates the aqueous particles. From the liquid thus obtained, it does not, however, appear that more than 15½ per cent. of dry albumen exists; for if it be exposed to a low gradual heat, it will lose about 80 per cent. of water, and 4½ of a liquid uncoagulable matter. According to the best analysis, it is composed of

Carbon	52.883
Oxygen	23.872
Hydrogen	7.540
Nitrogen	15.705
	100.

The most remarkable property of albumen is that of its coagulating or forming a white solid substance, by the application of gentle heat. At the temperature of 160° Fahr. it solidifies, and is then insoluble in water. On this account, its existence in water may be easily detected. According to Dr. Bostock, if water contain $\frac{1}{1000}$ of its weight of albumen, it becomes opaque on boiling, by the coagulation of this substance. It may also be coagulated by a powerful voltaic battery. If, after coagulation, a continued heat be applied, a semi-transparent horny substance is formed. Albumen is soluble in water by agitation, but the coagulum is not, unless artificial pressure be applied; this may, however, be dissolved by most of the acids. It is generally supposed that a minute quantity of sulphur exists in albumen. If the serum of blood is evaporated in a silver vessel, a coat of sulphuret of silver is formed: this also occurs when a spoon has been dipped frequently in a boiled egg. Albumen is a delicate and valuable test for that fatal poison, corrosive sublimate, which it precipitates from its solution in white flocculi. It also renders the poison inert, and is therefore employed as a remedy. A valuable cement for joining earthenware, china, stone, &c. is made by mixing albumen diluted with water and quick lime. This cement will harden under water, and *sets* in the open air almost immediately. Albumen is very extensively employed in clarifying wines, and also in rendering leather supple. It undergoes decomposition rapidly if exposed to the atmosphere, and emits a very nauseous odour. The coagulated albumen is not liable to decomposition.

ALCHEMY. The word is derived from the Arabic *al* (the) and *kemia* (excellent), and signifies the most exalted science. It is a branch of chemistry, the objects of which were the transmutation of inferior metals to gold; the discovery of an elixir vitæ, or universal medicine; an universal solvent; and other visionary and impracticable schemes. The Saracens are supposed to have first introduced the art into Europe; and so eagerly was it pursued by many of the most exalted in station and even in knowledge, that monarchs have not been ashamed to practise it, or to be duped by it. It is said that the Emperor Caligula endeavoured to obtain gold from the sulphuret of arsenic; and Edward I. witnessed an attempt made by Raymond Lully to obtain the precious metal from iron, which it was believed he accomplished. Most of the alchemists imagined that gold was the only elementary metal, and that the others were merely gold contaminated by foreign matters, from which it was possible to separate it. It was also imagined that mercury might be solidified, and that silver would be the result. In these futile pursuits many lives were spent, and splendid fortunes sacrificed. The art of the professors of alchemy was shrouded in mystery, which none but the initiated could penetrate. Their language was symbolical, and they either believed or propagated the notion that supernatural influence was necessary, and might be commanded in their pursuits. The student was sometimes required to qualify himself for the attainment of his object by acts of devotion and charity. The operations were by some only attempted when planetary influence was supposed favourable to success. So many exalted persons became the dupes and victims of the professors of alchemy, that in the reign of Henry IV. an act was passed prohibiting all attempts to make gold or silver under the pain of felony. From the numerous well-authenticated instances of persons having procured gold by certain mystical operations with the aid of fire, it is generally believed that a fraudulent slight of hand was practised. A hollow rod, containing gold dust, is said to have been employed in stirring the contents of the crucible, or the precipitated solution of gold used as a component in the powder of projection. In these ridiculous attempts, however, many valuable chemical discoveries were accidentally made. Porcelain china was first obtained by an alchemist in search of the philosopher's stone.

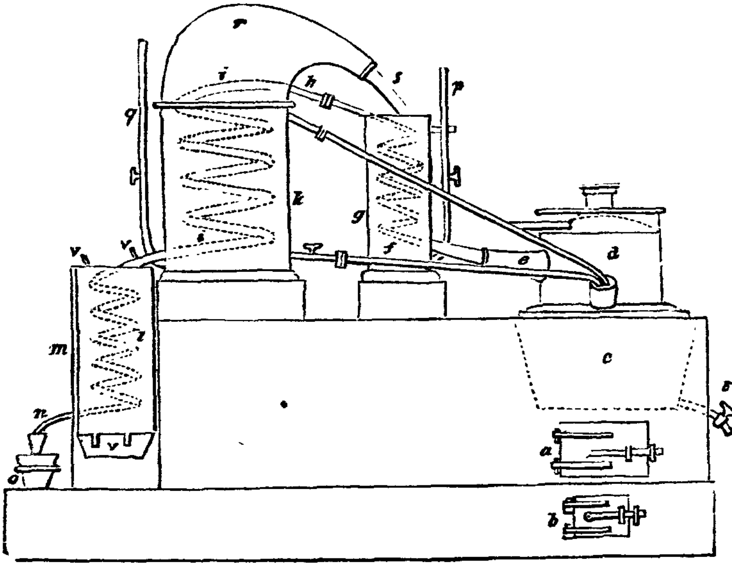
ALCOHOL. The purely spirituous part of liquors, which have undergone the vinous fermentation. It is the product of the saccharine principle formed by the successive processes of vinous fermentation and distillation; and all fermented liquors will afford it. Although brandy, rum, arrack, malt spirits, and the like, differ much in colour, taste, smell, and other properties, the spirituous part, or alcohol, is the same in each. The chief properties of alcohol are the following: It is a colourless transparent liquor, very movable and light, from which cause the bubbles formed by shaking it subside instantly. Its smell is poignant and agreeable, and its taste hot and pungent. It is so exceedingly volatile as to be converted into vapour by the heat of the hand; when exposed to the air, it evaporates at 10° above the freezing point, and leaves no residue except a little water, when not quite pure. It boils at about 165° Fahr., and it is generally supposed that it cannot be frozen, although Dr. Hutton asserts that he succeeded in freezing it; but as he kept his method a secret, no one has been able to repeat the process. Alcohol, when heated in contact with air, if it be pure, burns with a light flame, without leaving any residue, and yielding by the combustion a vapour, which is found to be nothing but water, and the weight of which Lavoisier found to exceed by $\frac{1}{7}$ part the weight of the alcohol consumed. Alcohol mixes with water in any proportion, giving out heat by the mixture; and a mutual penetration of the parts takes place, so that the bulk of the two liquors, when mixed, is less than when separate. So strong is the affinity between these two fluids, that water is capable of separating alcohol from many of the substances which may be united with it; and again alcohol decomposes most saline solutions, and precipitates the salts. The following substances are soluble in alcohol in different proportions: all the alkalies, when pure; several of the neutral earths and metallic salts; sulphur in vapour; phosphorus slightly; the essential oils; and the odorous part of vegetables, resins, and gum-resins, wax, spermaceti, biliary calculi, &c. The following substances are insoluble in alcohol:

the alkaline carbonates; all the sulphates; some of the nitrates and muriates; metals; metallic oxides and metallic acids; all the pure earths; the fixed oils, unless when united to alkalies, or converted into drying oils by metallic oxides; muscular fibre; the coagulum of blood; and albumen. To ascertain the purity of alcohol, various methods have been devised. It has been thought that alcohol which burns readily and leaves no residue is very pure, but this test is fallacious, for the heat produced is sufficient to dry up part of the water. Another method is, to drop a small quantity of it on gunpowder, and set fire to the spirit, and if the spirit be pure, it will burn quietly on the powder, and the last portion of it will ignite the powder, but if the spirit be watery, the powder will not explode. This proof is, also, not to be depended upon; for if any considerable quantity of even the best alcohol be poured on a small quantity of powder, the water which it affords as it burns, moistens the powder and prevents it from kindling; and if it be only barely moistened, any spirit that will burn will inflame it. The most accurate method is to find its specific gravity by a hydrometer, noting carefully at the same time its temperature. The uses of alcohol are very numerous, and it is extensively employed in medicine and the arts. In combination with copal, resin, &c. it forms varnishes. From its antiseptic power it is well calculated to preserve anatomical preparations. Its gentle and steady heat, unaccompanied by smoke, renders it eligible for burning in lamps; and from the impossibility of freezing it in any known degree of cold, it is well adapted for indicating the lower degrees of temperature in the thermometer. Having thus briefly noticed the properties and uses of alcohol, we shall proceed to describe the process by which it is obtained, giving, at the same time, an account of several modifications of the apparatus employed, which have been recently invented, and embracing a description of the most improved French distilling apparatus. The substances from which alcohol is chiefly prepared, are the juice of the grape, molasses, grain, and the farina of potatoes; these substances containing a large portion of saccharine matter, which is the basis of the vinous fermentation. The mode of extracting this saccharine matter depends upon the nature of the substance operated upon; but a saccharine solution being obtained, the mode of converting it into alcohol is the same for them all. The solution is first set to ferment, a certain quantity of yeast or other fermenting principle being in some cases added. During the fermentation particular attention must be paid to the temperature; if it exceed 77° Fahr. the fermentation will be too rapid; if below 60° Fahr. the fermentation will cease. The mean between these points is considered as the most favourable, and the fermentation must be continued until the liquor grows fine and pungent to the taste, but not so long as to permit the acetous fermentation to commence. When the fermentation is finished, the liquor, if it be the juice of the grape, is termed *wine;* but if the produce of other substances, it is termed *wash.* The wine or wash is put into a still (of which it should occupy about three-fourths,) and distilled with a gentle fire, as long as any spirit comes over, which is generally until about half the wash is consumed. The form of the common still is too well known to need any *particular* description; it generally consists of a large boiler, made of copper, and fixed in masonry over a fire-place. The boiler has a head of a globular form, to which is soldered a neck, which, forming a complete arch, curves downwards, and fits into what is called the worm. The worm is a long tube, generally made of pewter, of a gradually decreasing diameter, and is curled round into a spiral form; it is enclosed in a tub which is kept filled with cold water during the distillation. The produce of the first distillation forms what is termed *low wines;* consisting of alcohol combined with a large portion of water, on an average about one part of alcohol to five parts of water. This is re-distilled, and affords proof spirit, consisting of equal portions of spirit and water. The proof spirit being returned to the still and re-distilled, the product is called spirits of wine or alcohol, being alcohol combined with a very small portion of water, from which it is impossible to free it by distillation, but which may be wholly or in great part removed by other processes, to be hereafter described. The first important improvement in the process of obtaining alcohol was introduced by a French chemist named Adam,

who, by a happy application of scientific principles, was enabled to dispense with the tedious re-distillations, and to obtain alcohol highly concentrated by a single operation; economising time, labour, fuel, and (what in many situations is highly important,) water for condensation; besides obtaining spirits of a superior quality, with an increase in the quantity produced. The principle of his invention consists in causing the vapour of the wine, with which the still is charged, to pass through a quantity of wine contained in a vessel placed between the still and the refrigerator, by which the vapour is condensed, and imparts its heat and alcohol to the wine, until at length it enters into ebullition; and as this wine, besides its natural portion of alcohol, has received the alcohol contained in the vapour of the wine in the still, its vapour will be more highly charged with alcohol than the former, and this vapour in its turn is condensed in another vessel similar to the former, and so on through a number of vessels in succession, until it arrives at the refrigerator highly concentrated. His apparatus in its arrangement resembled "Wolfe's apparatus:" between the still and the refrigerator were placed three or four strong copper vessels, named eggs, from their shape. From the head of the still a pipe proceeded to nearly the bottom of the first egg, and from the top of each egg, a similar pipe proceeded to nearly the bottom of the next egg in succession, the pipe from the top of the last egg being connected to the worm, which first traversed a vessel or reservoir containing wine, and then passed through a vessel containing cold water. From the wine reservoir a pipe went to the still, communicating also with the bottom of the eggs, by means of cocks, for the purpose of charging the still and eggs with the liquid for distillation, the several vessels being each filled about three-fourths. When ebullition takes place in the still, the vapour issuing from it is condensed by the wine in the first egg gradually raising its temperature until it likewise boils, and its vapour (which is richer in alcohol than the vapour from the still) is in like manner condensed in the wine of the second egg, and so on through the remaining eggs, the vapour issuing from the last into the refrigerator being highly concentrated. The upper part of the refrigerator being immersed in the wine reservoir, the alcoholic vapour in its passage through the refrigerator gives out a portion of its heat to the wine by which it is surrounded, and is finally condensed by the cold water in which the lower portion of the refrigerator is immersed. When the vapour from the still no longer contains alcohol, the contents of the still are discharged, and the still is re-charged from the first egg, which is charged in its turn from the second, and so on throughout the series, the last egg being charged from the wine reservoir, the wine in which has been already considerably heated by the passage of the alcoholic vapour through the refrigerator. Although the principle of this invention is admirable, and has served as the basis of a great part of the subsequent improvements in distillatory apparatus, yet, as was to be expected, improvements have been introduced in the construction and arrangement of the parts, several of which we shall lay before our readers, for which reason we omit giving a drawing of the original.

About the same time that Adam introduced the important improvement just described, M. Solimani, Professor of Natural Philosophy in the Central School of the Gironde, contrived to obtain the same results by a different method. The principle upon which his invention is based is, that water to exist in the state of vapour requires a temperature of 212° Fahr., whilst alcohol boils at about 165°; and that if a mixture of the two vapours be exposed to any temperature between these two points, a portion of the watery vapour will be condensed, which will be greater in proportion as the temperature is below 212°. The annexed figure represents Solimani's still, as improved by Curadau. *a* is the door of the furnace; *b* the ash-pit; *c* the boiler, with a large cylindrical head *d*; *e* the exit tube for the vapours, connected by a union joint to the worm *f* in the tub *g*. This tub is filled with water, which is to be maintained at a temperature depending upon the strength of the spirit required, and the spirituous vapour that passes upwards through the worm *f* along the tube *h*, then descends through the worm *i i* surrounded with wine, in the vessel *k*, where it becomes condensed. The liquid spirit then runs through another worm *l*, surrounded by

cold water, which completely cools it before it is discharged by the pipe *n* into the recipient *o*. To prevent the water in the tub *g* from becoming too hot by the passage of the heated vapours through the worm *f*, and to preserve it at an even temperature, cold water from an elevated cistern is introduced at the

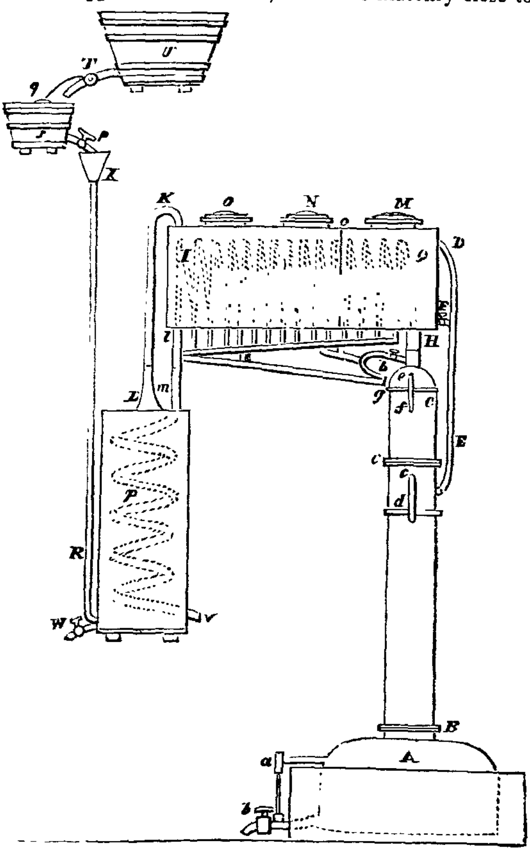


bottom by a pipe *p*, the quantity being regulated by a stop-cock; and the wine which surrounds the worm *i i* in the tub *k* is supplied from a vessel above, by means of the pipe *q*. This wine in the course of distillation grows hot: it is therefore used to charge the still as often as the former charge is worked off, and the spent wine drawn off by the cock *t;* and as it is economical to take off the hottest portion, the cock *q* is opened, when the cold wine from the cistern above enters at the bottom of *k*, and forces the upper or heated portion along the pipe *u* into the boiler of the still. The spirituous vapours formed in the tub *k* are conducted by the head *r* and the curved neck *s* into the worm *f*, where it takes the course of the vapours which proceed from the still. The tub *m* is kept as cold as possible by an ingenious contrivance of M. Curadau. A number of spiral pipes surround the tub on the inside, the ends of only two of which are shewn in the figure to avoid confusion. Now, as the upper part of the tub is always the warmest, a current of air is produced in these pipes, which serves to cool the water in which they are placed. The worm *f* being surrounded with a medium of about 180° Fahr. returns to the still the greater portion of the watery part of the vapours, so that by this apparatus spirits of great strength may be obtained at a single operation.

Berard's Improved Still. This invention consisted in the application of a lofty neck and head to the body of a common still, which, being exposed to the cooling influence of the air, a considerable condensation took place in those parts, but the liquor thus re-formed was not permitted to run back immediately into the boiler, but to fall upon partitions with raised ledges, so that the ascending vapour had to traverse over the successive layers of fluid in the partitions, and became for the most part condensed in its passage, only the strongest or purest spirit passing beyond the head.

Instead of a more particular description of Berard's method, we shall proceed to the notice of Mr. Derome's still, in which the method is introduced with considerable improvements. This apparatus consists of seven vessels or parts,

performing separate offices: namely, a boiler A; a distilling column B C; a rectificator C C; a condenser I Q; a refrigerator *p;* and a reservoir *s;* in which the supply from another vessel U is regulated. It is considered preferable to have two coppers like that at A, set in the masonry close to each other



so that the heated air from the burning fuel under one copper may be conducted under the other. Two communications are also to be made between the two coppers, the first by a pipe proceeding from the bottom of A to the upper part of the other; the second by another pipe rising from the top of the latter, (not represented) and descending through the top of A to the bottom of the vessel, to carry all the vapour generated underneath the liquid therein. At *a b* is a glass tube to show the exact height of the liquid in the copper. The interior of the distillery column, B C where the separation of the alcohol takes place, is full of shelves perforated with small holes, through which the vapour from A necessarily passes as it ascends, and comes in contact with the wine or liquid to be distilled, that passes through the same apertures; both the wine and the spirit are thus retarded in their progress, and become intimately mixed. The small tube *c d* is of glass, to show the state of the process going forward in the rectificator C C, which is only an extension upwards of the column beneath, containing similar perforated shelves, and provided with a glass tube *e f* to show the state of the process in this part. The vapour rising to the top of the rectificator passes out through the neck H into a long worm, coiled horizontally in the condenser I Q, which is a copper cylinder. This vessel contains wine

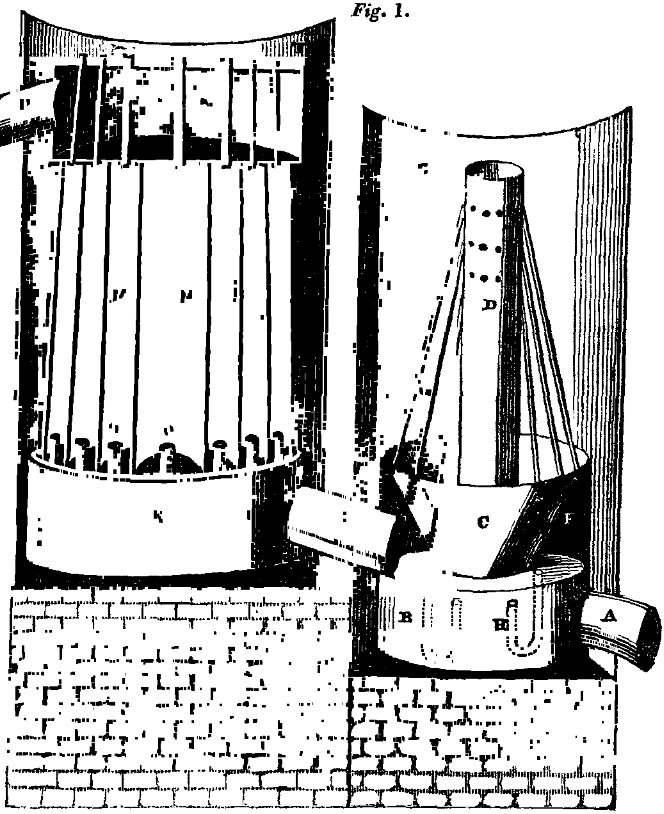
that becomes heated by passing through the worm. To collect the spirit that becomes condensed in the worm, the lower side of each coil has an opening into a short tube, of which there are as many as there are coils to the worm. To these tubes there are cocks, to draw off, as may be required, the products of any or all of them (the most distant from the rectificator being of course the strongest spirit,) either into the refrigeratory, by the upper long inclined tube represented, or by the lower one back again into the rectificator for a second rectification. The condenser is divided into two chambers, by a partition *o*, with a communication between them at the lower part; there are also three manholes closed by lids M N O in the condenser, for the convenience of having it cleaned; and it has a cock F to draw off its contents. The wine is constantly supplied to the condenser by the pipe K L, and as constantly flows off by the tube D E. *p* constitutes the refrigeratory or cooler, and is also a copper cylinder containing a worm, that receives the condensed vapours through the pipe *l m*, and delivers the cooled product through the opening V. The cooler is constantly supplied with cold wine by the pipe R, which enters at the bottom of the vessel, and the wine passes off at the top of the vessel by the pipe K L into the condenser I Q. W is a cock, to empty the cooler; S is the reservoir which contains the wine; it has a cock *p*, by the opening of which the quantity of wine to be supplied to the apparatus is regulated; and in order that this may be equal, the liquid is kept at a uniform height by means of a ball cock *q* T, the pipe to which is connected with the principal reservoir, which, for example, may be the vessel U.

Mode of conducting the operation. The cock *p* being opened, the wine from U passes through all the vessels into the two coppers, to the desired height, which is ascertained by the two glass gauges. The distilling column is charged with as much wine as will prevent a free passage of the vapour; and when the condenser and cooler are full, the entrance of more wine is stopped, and the communication is not re-established by the cock *p* until the wine in the coppers has parted with its alcohol, and the liquid in the condenser is hot enough to be introduced into the distilling column. After this, a small stream, proportioned to the size of the apparatus and the rapidity of the work, is kept constantly running from S, and then begins what is termed the *continued process*, all the previous work being only preparatory. After this, the supply of the vessels with wine, the evaporation, condensation, and cooling, go on independently, requiring only attention to the fire.

Winter's Patent Distilling Apparatus consists of two vessels of a peculiar construction, which may be applied to stills of every form; and will enable the distiller to extract the whole of the spirit contained in the wash at one operation, instead of the repeated distillations necessary in the usual mode. These two vessels contain condensers, which, as in Solimani's apparatus, are surrounded by a fluid maintained at such temperatures, as to condense any desired portion of the aqueous parts of the vapour from the still before it enters the refrigerator. The apparatus is shown in the annexed Fig. 1. A is a tube by which the vapours enter from the still into the first receiver B; C a conical surface or plate; D the principal vapour tube, which being closed at the top, the vapours descend by the small tubes G into the chamber F. These small tubes are placed all around the principal tube, which are inserted in the holes shown in the engraving just above D. The apparatus is surrounded with water heated to 170°, and is contained in the tub or bath T, shown in section; and as the vapours contained in the tubes are, by this arrangement, separated into small portions, a rapid condensation of the aqueous parts takes place. A number of bent tubes, as at H, are fixed in the annular plate, which covers the receiver at B with their upper ends, a little above the surface, which serve to carry off the condensed liquid back into the receiver B. The vapour improved in its spirituosity, is then collected in the chamber F, and passes from thence by the tube I into the second receiver K. The top plate of this receiver K, as well as the bottom plate of the third receiver N, have a number of openings or apertures forming concentric circles, as at L L, Fig. 2, in the plan of the apparatus, which we also annex. Into each of these annular apertures L L are fixed two copper cylinders,

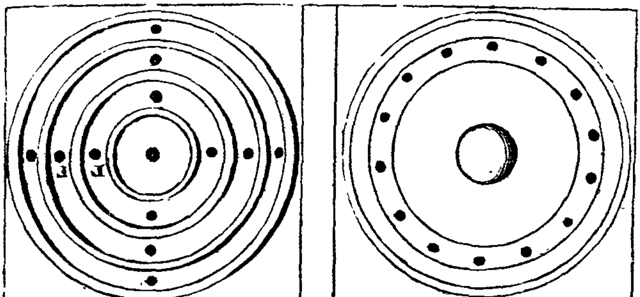
one within the other, and only a quarter of an inch apart; and as there are four such apertures, there are consequently eight cylinders, or four pairs in the apparatus, which are exhibited in section in the annexed Fig. 1. at M M. O O

Fig. 1.



are tubes which pass through the receiver at K, to convey water between the cylinders; similar tubes are passed through the receiver N, by which means the water is diffused over every part of the extended surface of the apparatus,

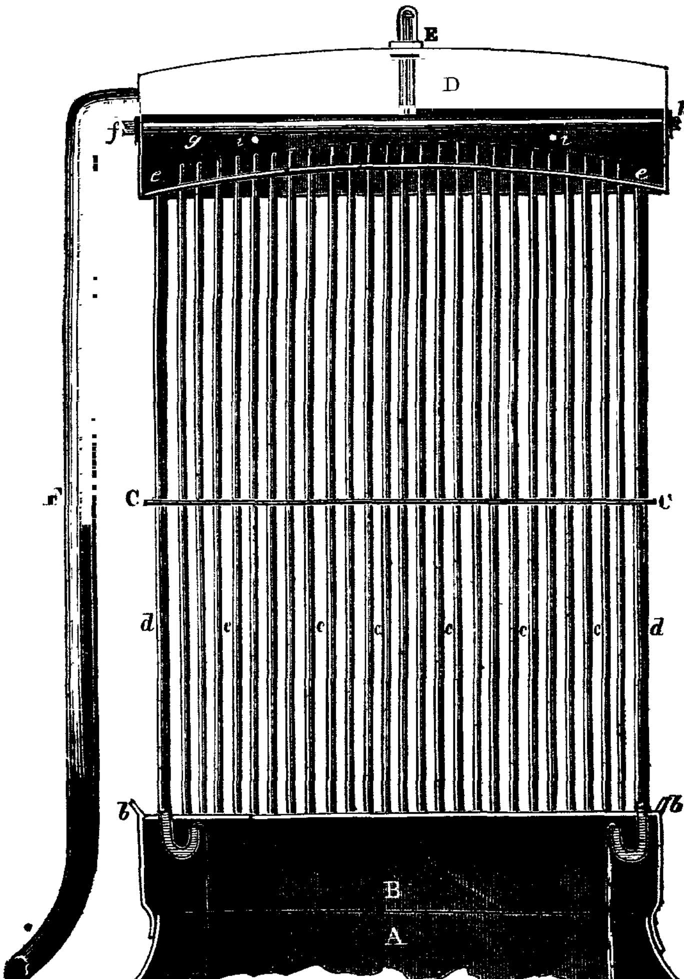
Fig. 2.



effecting thereby almost as rapid a condensation of the aqueous portion of the vapour, as if the water were in actual contact with it. The vapours from the

lower receiver K ascend, as before mentioned, through the narrow spaces between the cylinders into the upper receiver N, in a high state of purity and strength. From this last hold it proceeds into the worm by the tube P, where it is instantly condensed by the refrigerating effect of the cold water, by which this part of a distillatory apparatus is always surrounded. The water contained in the second bath T, shewn in section, is heated to 140° (or less, as the strength of the spirit may require,) that being a temperature at which the vapour of water, as well as that from the empyreumatic oils, cannot exist. This apparatus is stated to be so effective, that in an experiment made at an eminent distillery in London, in the presence of several experienced distillers, "feints 80 per cent. under proof were put into the still, and came out at one operation at 55 per cent. over proof."

Grimble's Patent Distilling Apparatus consists of a series of very small tubes, fitted to the mouth of an ordinary still, the upper ends being received

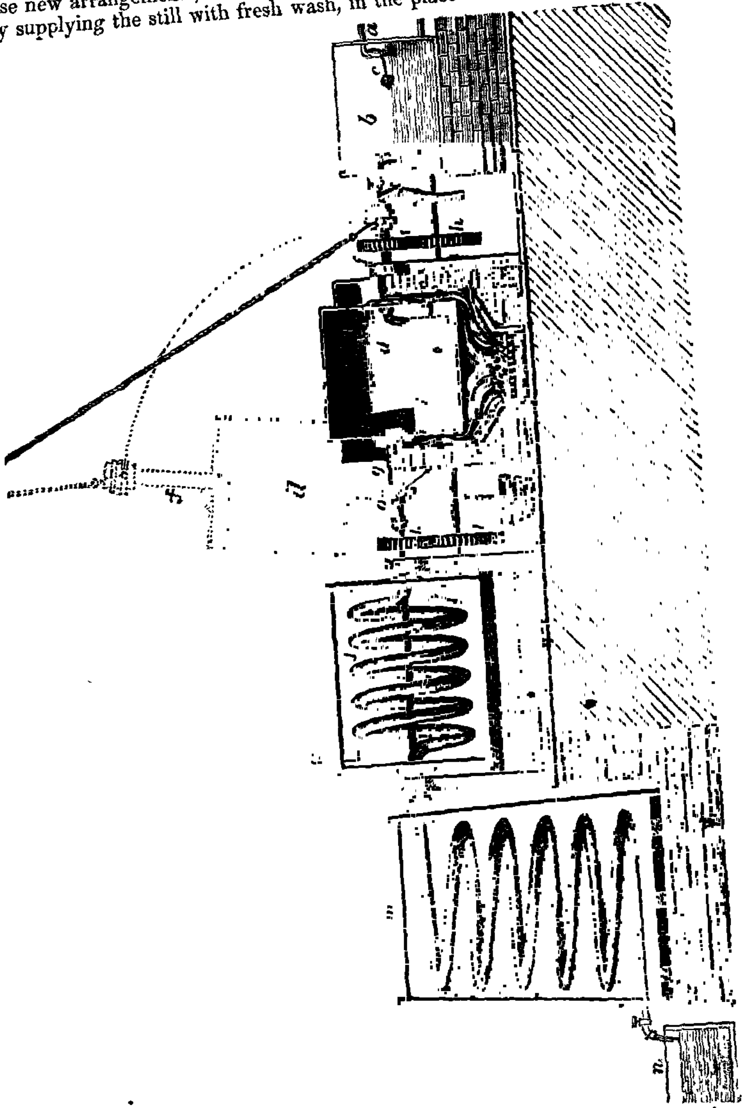


into a close box, from whence the uncondensed vapour passes on to the worm, whilst the condensed portion is returned to the still. It is shewn in the accompanying engraving, where A is the still; B the bottom box of the apparatus,

fitting on the still; *b b* a plate of copper, fitting on the box B; *c c c* are open tubes, through which the vapour ascends into the top box D, where the separation of the aqueous vapour takes place from the spirits; the tubes *c c c* project through the bottom plate of the box D, so that the oily and aqueous matters are not allowed to return by the small tube, which would impede the vapour issuing from the still, but run back into the still by the larger corner tubes *d d*, which are on a level with the bottom plate at *e e*. The lower ends of these tubes are turned up syphon-wise, to prevent the ascent of the vapour from the still. *c c* is a stay plate for the tubes; in the box B is a range of tubes *g g g*, through which a current of cold water is maintained when the spirit is required very strong, (but not generally used) having its egress and exit at *f h*. F is the pipe that conveys the spirituous vapour into the worm, and a thermometer at E serves to regulate the operations. We understand that an apparatus of this description is or was in use at Messrs. Booth and Co.'s distillery, but do not know how far it answered the proposed end.

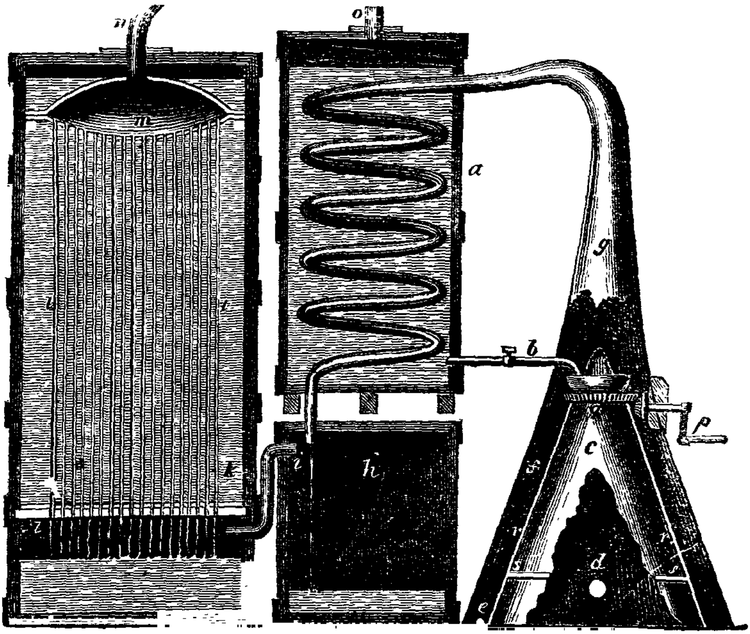
Evans's Patent Distilling Apparatus. The object of this invention is to effect a more equal and uniform distribution of heat to the liquid under distillation, than is obtained in stills as hitherto constructed, as well as obtaining spirits of great strength at a single operation. As the plan is totally different from any of the preceding ones, and as some of the arrangements evince great ingenuity on the part of the inventor, we lay it before the reader, without, however, expressing an opinion as to its applicability in practice. The engraving represents the whole operation at one view. *a* is a pipe which conveys the wash or fermented liquor into a reservoir *b*, where it is maintained at a certain level by the ball valve *c*. *d* is the still, which is a revolving copper cylinder, with ledges fixed in horizontal lines against the inner surface, to increase the agitation of the wash as it turns upon its hollow axis *f g*; its motion is derived from the spur-wheel *h* acting upon the pinion *i* fixed upon its hollow axis; *j* is the rectifier; this is formed of a large pipe of uniform bore, coiled up into the spiral figure exhibited, with the ends bent, so as to form axes for rotation, on one of which a pinion *k* (corresponding to that at *i*) is fixed; and this pinion is acted upon by another spur-wheel *l* on the same shaft as the other; *m* is the common distiller's refrigeratory; and *n* a receiver for the distilled spirit. The figure represented in dotted lines, is intended to show the position in which the still is drawn up when it is necessary to cleanse it. For this purpose there is at *o* a universal joint, of a peculiar construction, which enables it to be easily done, after having separated the connecting tubes at the union joint, represented contiguous thereto. The rectifier *j* communicates with the still through the hollow axle *g*, and with the refrigeratory through a stuffing-box; and the still communicates with the reservoir by means of a syphon passing through the hollow axis *f*. The outward part of the syphon has two unequal limbs; the short one is inserted in the reservoir for the purpose of charging the still with wash, and the long limb for discharging the spent liquor. In order to charge the still, the ball of the valve is pressed downward, so as to raise the liquid above the top of the syphon; this sets the syphon in action, and causes it to fill the still to the same level as the liquid in the reservoir. Thus prepared the fire is lighted, and a slow rotatory motion is given to the still by hand or any other convenient first mover, applied to the shaft upon which the spur-wheels *h* and *l* are fixed. The continuous motion of the liquid prevents the formation of empyreuma, however fierce the fire may be; and by the agitation of the liquid, and the intensity of the heat applied, a rapid production of vapour is caused, which immediately enters the hollow axis *g*, and passes into the coiled worm of the rectifier *j*. It is here necessary to observe, that this capacious worm revolves in the direction pointed out by the arrow; consequently whatever portion of the vapour becomes condensed in it, runs out at every revolution back through the hollow axis *g* into the still, and the hollow axis *g* is for this purpose made tapering wider towards the still, so as to give the liquid a descent to run freely into it. The vessel *j* is, therefore, properly termed a rectifier, as it separates the water from the diluted alcohol before passing out of it into the refrigeratory *m*. In this it arrives in a state more or

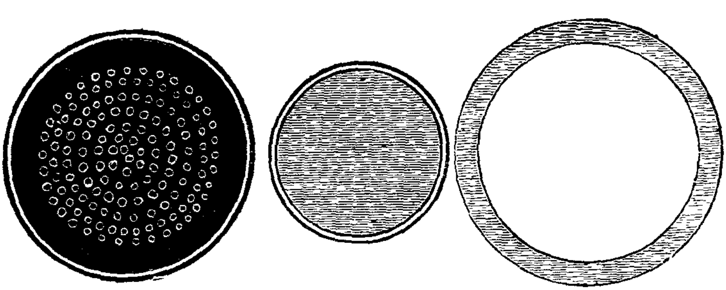
less concentrated, according to the temperature maintained in the rectifier, which is regulated as usual by a thermometer. The spirit may consequently be drawn at one operation at almost any desired strength. An interesting feature in these new arrangements, is the mode of applying the syphon, which is constantly supplying the still with fresh wash, in the place of that which has been



vaporized; and this operation is uniformly continued during the rotation of the vessel, owing to its passing through a tubular axis. The syphon in like manner enables the still to be discharged without stopping the machinery. When it is necessary to recharge the still with the fire under it, a thick cast-iron sliding plate is drawn from the back, so as to interpose itself between the fire and the still, and thus prevent any injurious effects to the contents of the latter.

The following engraving represents an apparatus which has been proposed for distillation by means of steam or heated air, acting through the medium of an extensive metallic surface upon a thin film of liquid, in order to promote a speedy evaporation at a comparatively low temperature. *a* is a tall cylindrical vessel containing the fermented wash to be distilled, which is supposed to be supplied



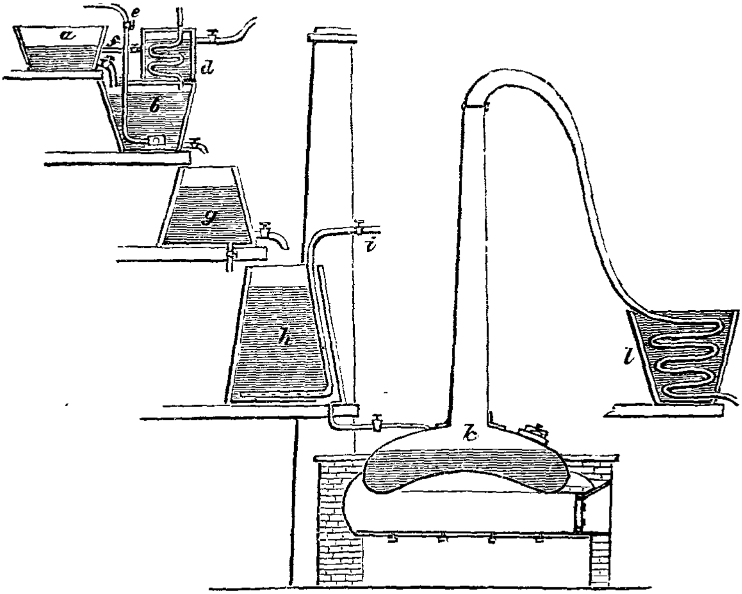


regularly by a pipe from the brewhouse. By turning the cock in the pipe *b*, the wash flows upon the exterior surface of the conical evaporator *c*, formed of thin copper. The liquid is first received into a small basin, surrounding the cone near its apex, having numerous small perforations at the bottom, by which means the liquid is equally diffused in a thin stratum over the surface of the cone *c*. *d* is the opening into the cone *c*, by which the heating medium is admitted, and provided with a valve or cock for regulating the temperature; and the heat being maintained at about 180° but a small portion of aqueous vapour would rise with the spirituous, and the spirit would thus be separated at the commencement of the process from those matters which usually contaminate spirits of home manufacture. That portion of the wash that escapes

evaporation owing to the low heat, (and which would consist chiefly of water and extractive matter,) will run off at the bottom of the cone by a circular gutter, and from thence pass out by an aperture or pipe, as at *e*, while the more spirituous rises between the inner cone *c* and the outer cone *f f*, enters the neck *g*, and from thence proceeding through the spiral worm, shown in the wash vat *a*, is received into the recipient *h*, partly in the form of vapour, and partly in the liquid state; having in its passage through the worm communicated so large a portion of its heat to the wash in which the worm is immersed, that a slight additional heat will be sufficient to separate its alcoholic constituents. A small portion of strong spirituous vapour will collect in the upper part of the vat *a*, which may be conducted off by the tube *o* into a separate recipient or refrigeratory, as the spirits thus produced will be of superior purity. The more volatile portion of the vapour passes onwards through the open tube *i* into the great refrigeratory *k*. This is a large cylindrical vessel or vat, with a strong false bottom at *l*, into which are soldered a great number of small thin pipes *t t* rising vertically and open at both ends, the upper extremities being soldered into the bottom plate of the chamber *m*. The portion of the vat above the false bottom *l* is kept filled with cold water by a service-pipe inserted at the lower part, the vapour, therefore, rising up through the pipes *t t*, is exposed very much subdivided to a very extended metallic surface, surrounded by cold water, by which its caloric will be very rapidly abstracted; the condensed liquid which then runs back down the pipes, meets with the rising vapour in its progress, and, by that means, condenses a further portion at a higher temperature than would have otherwise been accomplished, which is the object of causing the vapour to proceed upwards instead of forcing it downwards, as in the ordinary practice. By these arrangements it is expected that very little vapour will reach the upper chamber *m* if the water is not allowed to get above 80°; but if the supply of cold water should be insufficient for the purpose, the vapour must proceed, of course, from the tube *n* to another refrigeratory. To a bevelled wheel at *q* are attached two long bars, or scrapers *r r*, the edges of which scrape or brush against the surface of the cone to clear it of sediment or incrustrations, which will then fall to the bottom; the bars are connected by a ring at *s*; such an apparatus will be useful in the distillation of liquids that contain much extractive matter. From the above description it will be seen that the distillation is carried on without intermission, the wash being admitted in a small stream, in such quantity as to allow the alcoholic portion to be evaporated in its passage over the heated surface of the cone *c*, and the remaining portion to pass off in a stream by the waste pipe at *e*, as long as fermented wash is supplied from the brewhouse. It has been stated, though we know not upon what authority, that it has been found difficult to separate the alcoholic from the aqueous parts of fermented liquors, by simply causing them to flow over a heated surface; and that preference has therefore been given to stills constructed upon the combined principles of Adam and Solimani.

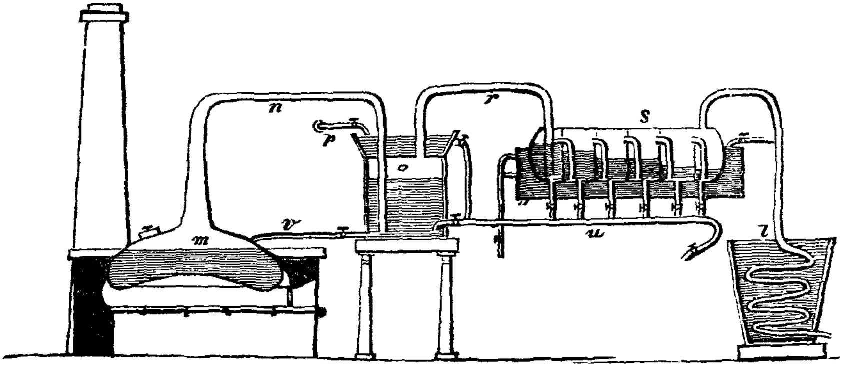
We have already mentioned the pulp of potatoes as amongst the substances from which alcohol may be obtained; and the manufacture has been for some time past carried on in various places with great success. The apparatus and process which we are now about to describe, are both of foreign invention, and were introduced into this country by the patentee, M. Saintmarc, of the Belmont Distillery, Vauxhall. The potatoes being first washed clean, are taken to a mill and ground into pulp. This pulp is then mixed with a large quantity of water, which takes up the chief part of the contaminating brown colouring matter, and it is then poured through a coarse sieve, which, detaining those pieces that have escaped the mill without being ground into pulp, they are rejected as ineligible for fermentation, and applied to the feeding of pigs. The pulpy liquid thus freed from the coarser pieces, runs into a trough containing a number of small holes, and lined in the inside with a linen cloth sufficiently fine to prevent the floating particles of starch from passing through; the water then drains through the linen, leaving the pulp and starch to settle in a mass. When it has sufficiently drained, and become solid and compact, it is removed from thence and laid upon a plastered floor, which rapidly absorbs a great portion of its moisture.

To dry it entirely, it is afterwards placed in a kiln or stove, which completes that part of the process. In the dry state the pulp may be kept uninjured for years, and may therefore be stored away for future use. The wet pulp being, however, equally serviceable for immediate fermentation, there is no occasion to dry it if the several processes in distillation can be carried forward at the time



Supposing the pulp to be used in the dry state, it is cut, or broken to pieces, and mixed in the vat *a*, with sufficient hot water to bring it to the consistence of cream. The vessel *b*, lined with lead, and called the decomposing vessel, is then to be supplied with water to the depth of about six inches; to this, a quantity of sulphuric acid is to be added, in the proportion of three pounds of acid to every hundred pounds of dry pulp; but only ten pounds of the acid to every hundred pounds of the wet pulp. The diluted pulp is then to be discharged from the vessel *a*, through the cock into *b*, containing the diluted acid; steam is then to be admitted from a boiler, (not shown in the engraving,) by turning the cock in the pipe *e*, which descends to the bottom of the vessel, where it is made to issue from a steam-box; the heat causes the mixture to boil, and, after four or five hours' ebullition, the decomposition is considered complete. Before, however, describing the next part of the process, we should notice that a worm-tub *d*, supplied with water from a service-pipe, is placed on the top of the decomposing vessel; the vapours from the boiling liquid beneath enter this worm, and are therein condensed by transmitting their caloric to the surrounding water; and the water thus made hot, serves for replenishing the vat *a* with fresh portions from time to time, as it may be required, by means of a connecting tube *f* furnished with a stop-cock. The contents of the vessel *b*, after decomposition, are discharged into the saturating vessel *g*, and, during the time that it is running, a quantity of lime, or chalk, in solution, may be poured in among it as long as any effervescence continues, which will vary according to the degree of concentration of the acid; but, in general, three pounds of chalk, or lime, will be found sufficient to saturate each pound of sulphuric acid employed in the preceding part of the process. The liquid in the saturating vessel having now become transparent, it is to be drawn off into the fermenting vat *h*, placed beneath, leaving the precipitated sediment undisturbed

at the bottom while the clear liquor is running. The discharge cock being closed, the sediment may be stirred up with a quantity of water, to take up whatever saccharine or fermentable matter it may contain; this should be allowed to subside again, and the clear liquor then to be added to the former in the vat beneath. To promote the fermentation, a quantity of yeast is now to be added to the liquid, in the proportion of three pounds to every hundred pounds of potatoe pulp. During the fermentation, which usually occupies from fifteen to twenty days, the temperature of the liquid should be preserved at from 90° to 100° Fahr., and the atmosphere of the room where it is conducted, at from 80° to 85°. The patentee having discovered that the introduction of hydrogen gas facilitates the fermentative process, besides increasing and improving the product, further directs that the vat should be furnished with a tube *i*, along which the gas is to be forced, by means of a pump, into the liquid. The tube, after descending to the bottom of the vessel, takes a horizontal serpentine course; in this part it is perforated with numerous small holes, through which the gas escapes and bubbles up through the liquid. This injection of the gas should be continued until the carbonic acid gas, in the upper part of the vat, contains an excess of the hydrogen. The patentee is of opinion that the introduction of hydrogen gas may be very advantageously used, not only in this process, but in the fermentation of all matters from which spirit or alcohol is to be extracted. When the vinous fermentation has ceased, the liquor is to be drawn off through the tube into the still *k*. This still is of the ordinary construction, except that instead of having a large head, or capital, it has a long neck rising perpendicularly from the body, the object of which is, that the aqueous part of the vapours may be condensed before entering the inclined part, and fall back into the still, while the more volatile or spirituous pass on alone into the bent arm, and from thence into the refrigerator or worm-tub *l*, where it is converted into the ordinary first product of distillation, called low wines (which is a very weak spirit). The low wines are then taken to another called the low wine-still, a section of which is shewn in the accompanying engraving.

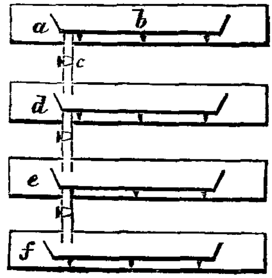


m is the body of the still fixed in brick-work over a furnace; a long perpendicular neck proceeds from this as in the wash-still, the object of which is, that the aqueous part of the vapour may be condensed as it ascends, and fall back again into the still, while the more volatile and spirituous passes on through the tube *n* to the bottom of the vessel *o*. This last-mentioned vessel has a tub of cold water placed on the top of it, which is kept supplied by the service-pipe *p*, and as the tube *n* passes through this tub, the greater part of the vapour at first condenses and is received into the vessel o in a liquid form; but as the vapour is continually coming over from the still, the condensed liquor is at length made to boil: the vapour filling the upper part of the vessel, from thence passes up the tube *r* into the long cylindrical vessel *s*, which is partly immersed in a long cistern constantly supplied with cold water by the usual means. The

cylindrical vessel *s* is divided by five vertical partitions into six compartments, but having a communication from one to the other by means of bent tubes proceeding from the upper part of the first compartment, to the lower part of the second; and, in the same manner, from the second to the third, the third to the fourth, and so on. It will now be readily seen that the most aqueous part of the vapour will be condensed in the first compartment, while the more vola tile passes to the second, where another portion of the vapour assumes a liquid form; the more volatile still will proceed to the third, and thence to the fourth, fifth, and sixth, according as the spirit is more or less divested of aqueous particles, all depending, of course, upon the degree of heat employed in the furnace for raising the vapour in the still *m*, and upon the degree of coldness of the water surrounding the condensing vessels. To ensure, however, the condensation of all the vapour, a tube *g* proceeds from the upper part of the sixth compartment, rises to a considerable height, then takes a horizontal course, and, finally, descends into a spiral worm placed in a tub of cold water, where, making a long circuitous passage, it is delivered from the bottom into a receiver in so concentrated a form, as to be nearly in the state of pure alcohol. At the bottom of the cylindrical vessel *s*, a separate short pipe, with a cock, proceeds from each compartment, leading into the long pipe *u*, which being also furnished with a cock at either end, the spirit contained in any compartment may be drawn off distinctly; the contents of any, or all of the pipes, may likewise be drawn off by the pipe *u* into the vessel *o* for redistillation; and the vessel *o* may be discharged back into the still when desired, by the pipe *v* having a cock for that purpose. Although this apparatus is well adapted for its intended purpose, and is new in this country (where the vexatious nature of the excise laws preclude, in a great measure, any improvements in the art of distillation) we must observe that little invention has been displayed on the part of the patentee, as almost every part of it is copied from apparatus long since invented, and in use in France. For a further account of distillatory apparatus, we refer our readers to the article DISTILLATION, under which head will be found a description of a great variety of stills and apparatus connected therewith, which the length to which we have extended the present article prevents our noticing in this place.

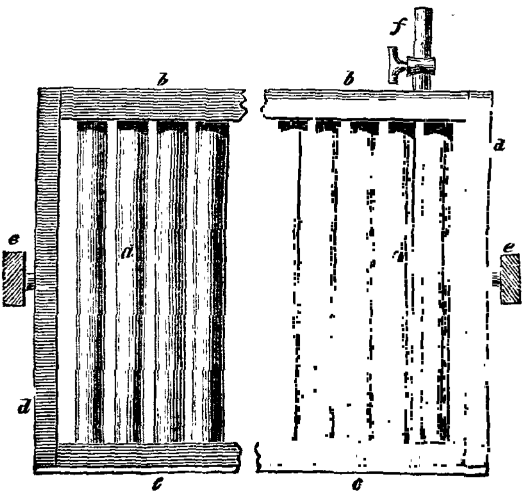
When, by repeated distillation, the alcoholic mixture is brought to a certain degree of concentration, the affinity of the alcohol for the water with which it is still combined, aided by the great excess in the proportion of the alcohol to the water, becomes so great, that no further separation of the constituent parts of the mixture can be effected by distillation. Alcohol being much lighter than water, its spec. grav. is used as a test of its purity. Fourcroy considered it as rectified to the highest point when its spec. grav. was 829, that of water being 1000; and this is, perhaps, nearly as far as it can be carried by mere distillation. Alcohol, however, is not in this state pure (nor, indeed, is any process known by which it may be rendered anhydrous, or perfectly free from water); but it may be freed from a further portion of water by means of an alkaline salt. For this purpose, muriate of soda (common salt), may be advantageously employed, by first depriving it of its water of crystallization by heat, and adding it hot to the spirit. It is, however, considered preferable to employ the sub-carbonate of potash. About a third part of the weight of the alcohol should be added to it in a glass vessel, be well shaken, and then allowed to subside. The salt will be found to have absorbed water from the alcohol, which being decanted, more of the salt is to be added, and the process continued until the salt falls dry at the bottom of the vessel. The alcohol must now be subjected to final distillation in a water-bath, to deprive it of the red tint derived from the potash, as well as to free it from the alkali held in solution. A most important improvement upon this method of rectification has been invented by a French chemist. It consists in placing a quantity of dry muriate of lime, or other deliquescent salt, in a large shallow-covered vessel; in this is placed another vessel of smaller dimensions, and resting upon the bottom on short legs, and containing the diluted spirit (brandy for instance) to be concentrated; the outer, or larger vessel, is then covered down, and properly

luted, to prevent the escape of the spirit. A series of double vessels are arranged beneath the former, charged with the deliquescent salt only; and pipes of communication lead from one to the other, and are furnished with stop cocks. These arrangements, as well as the process, will be perfectly well understood upon reference to the annexed diagram. *a* is the vessel containing the deliquescent salt; *b*, that containing the dilute spirit; the cover of *a* being well closed and luted, it is left for several days to attract the water from the spirit; and when the former is supposed to be fully saturated with aqueous particles, the spirit in *b* (considerably improved in strength) is drawn off into *d* by turning the cock *c*. This second vessel being also provided with a stratum of muriate of lime, the process of concentration recommences by a farther abstraction of the water contained in the spirit. In like manner the spirit may be successively operated upon by the salts contained in the vessels *e* and *f*, and, if required, by an additional number of vessels, until alcohol of the greatest purity is obtained. As each vessel is successively emptied, the saturated salt is taken away and replaced with a fresh quantity of dry salt, when it is ready to operate upon another portion of spirit let on from above. There is another method by which the strongest alcohol may be obtained, although the process, as usually conducted, is rather dilatory. It has been ascertained that bladder is impervious to alcohol, although pervious to water; so that if a portion of alcohol be confined in a bladder, the water will be evaporated in the course of a few days, whilst the alcohol remains, but in a highly concentrated state. The following information on the subject is extracted from Ferrusac's *Bulletin, Mai*, 1828, and, we doubt not, may be turned to practical advantage.



M. Soemmering, in a memoir to the Academy of Sciences at Munich, states that alcohol in a vessel covered with a bladder, the latter not being in contact with the fluid, loses, when exposed to a dry atmosphere, much of its water, and becomes stronger; but if the vessel thus closed be exposed to a damp air, the alcohol attracts humidity and becomes weaker. In a second memoir the author states more particularly the effect of bringing alcohol into more immediate contact with the membrane. If a bladder be filled with 16 oz. of alcohol at 75°, and be well closed and suspended over a sand bath, or placed near a warm stove, so as to remain at the distance of more than an inch from the hot surface, it becomes in a few days reduced to a fourth of its volume, and is nearly or quite anhydrous. M. Soemmering prepares for this purpose calves' or beeves' bladders, by steeping them first in water, washing, inflating, and cleansing them from grease and other extraneous matters, tying the ureters carefully, and then returning them to the water to clear off more fully the interior mucosity. After having inflated and dried the bladders, M. Soemmering covers them with a solution of icthyocolla, one coating internally and two externally. The bladders thus become firmer, and the concentration succeeds better. It is better not to fill the bladder entirely, but to leave a small space empty. The bladder is not moist to the touch, and gives out no odour of alcohol. If the latter be below 16° Baumé, the bladder then softens a little, and appears moist to the touch. Bladders prepared as above may be employed more than a hundred times, although they at length acquire a yellowish brown colour, and become a little wrinkled and leathery. The swimming bladder of the salmon is not fit for these experiments. Alcohol of 72° was put into one of them, and after an exposure of thirty-two hours, it had lost more than one-third of its volume, and was weakened 12°: the alcoholic vapour was perceived by the *smell*. Of two bladders of equal size, into one was put 8 oz. of water, and into the other 8 oz. of alcohol. They were placed side by side exposed to a slight heat. In four days the water had entirely disappeared, whilst the alcohol had scarcely lost an ounce of its weight. Mineral waters, and the water of wells, evaporate and deposit on the interior of bladders the saline particles which they contain. If

the heat be conveniently managed, absolute alcohol may be obtained in from six to twelve hours. Solar heat is even sufficient to procure anhydrous alcohol. Wine placed in prepared bladders contracts no bad odour; it assumes a deeper colour, acquires more aroma and a milder taste, and becomes generally stronger. Spirits of turpentine of 75° contained in a glass vessel closed with a bladder, lost nothing in four years. Concentrated vinegar lost the half of its volume in four months; the other half acquired more consistency, and had no longer an acid taste. The water of orange flowers was about one-third evaporated in a few months, appeared to have a stronger odour, and, consequently, had lost nothing of its volatile principle. These experiments of M. Soemmering clearly establishing the fact that bladder is impervious to alcohol, we have no doubt that on account of the little heat necessary to effect this rectification, it may be one of great economy, if an apparatus can be devised for conducting the process extensively and with little labour. For this purpose we would suggest that, instead of the ordinary animal bladder, the œsophagus of oxen should be employed, as exposing a larger surface to the air, and as more convenient for fixing into a suitable framing, which might be placed in a heated apartment, or, in warm climates, to the heat of the sun. Such an arrangement is shewn in the following diagram. *a a* are the œsophagus bladders, distended

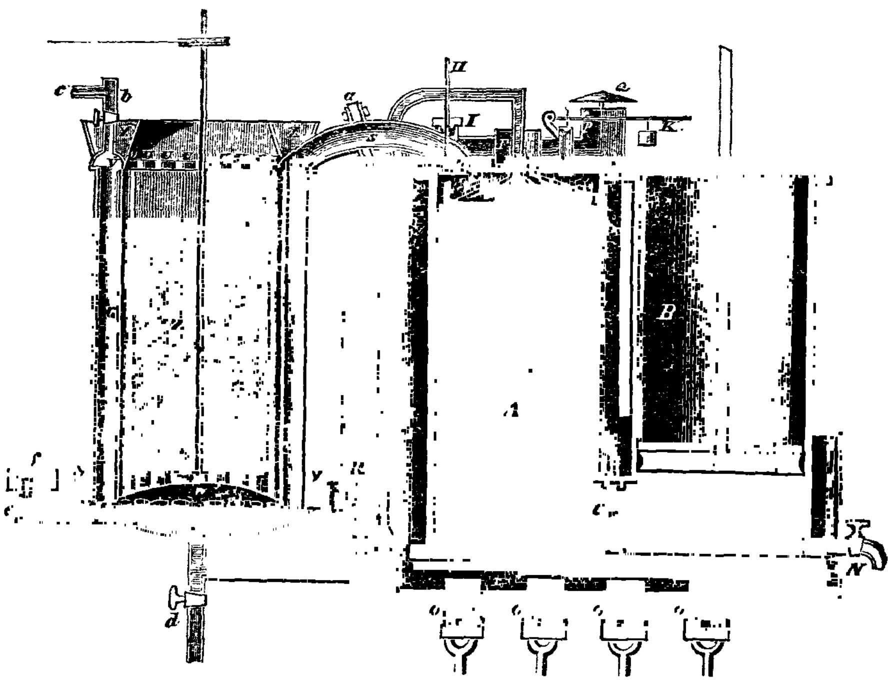


between a framing *b b* and *c c*, which is exhibited as broken away towards the middle, to show that it may be made of any convenient length or width. The bars *d d* connect the upper and lower pieces, and carry the pivots or axles which turn in the cross beams or supports *e e*, shewn in section. The upper side of the frame *b b* represents a square or round *tube*, in which are made circular apertures for the reception of the upper ends of the bladders *a a*, kept open and distended by wooden rings, and properly secured by cement. The lower ends of the bladders pass through similar apertures in the bottom rail, where they are cemented and kept closed up and secured from injury by a board screwed over them into the rail *c c*. We will now suppose that fifty (or any other number) of such bladders are fixed to a frame, and charged with diluted spirit, by means of a hose and nozzle connected to the cock *f*; that done, the cock *f* is to be closed. In the same manner let all the other frames in the apartment or manufactory be charged, of which there may be any number. In 100 frames 2000 or 3000 gallons might be suspended. The whole should then be submitted to a moderate heat, as of the sun, or a stove, &c. When it is found that the spirit has parted with its aqueous fluid in any of the frames, they are to be turned half way round on their pivots, by which the upper side

b b becomes the under, and the cock being opened, the concentrated spirit may be discharged by means of a hose into suitable recipients. Instead of a movable or swinging frame, a fixed one might be used, by forming the bottom rail (into which the lower ends of the bladders are inserted) of a tube similar to the upper one, and fitting it with a discharge cock.

From the circumstance of alcohol boiling at a temperature considerably below the boiling point of water, many persons have supposed that its vapour might be advantageously substituted for steam as a prime mover of machinery. The first suggestion to this effect we think originated with the Rev. E. Cartwright; but we are not aware of any attempts to carry it into effect previous to those of Mr. Howard, who took out a patent in 1825, for an apparatus for the purpose, and endeavoured with great perseverance to bring it to perfection, but, we believe, without success, as we cannot find that any engines of this description have been brought into use. The following description, with the annexed engravings, will explain the nature of the apparatus. A and B are

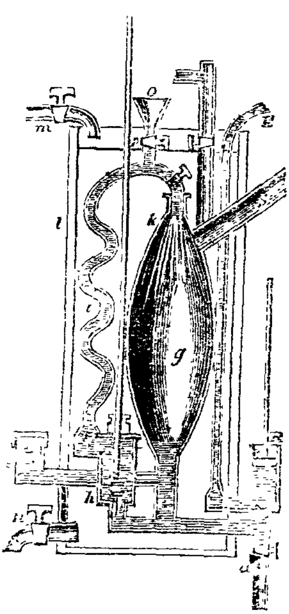
Fig. 1.



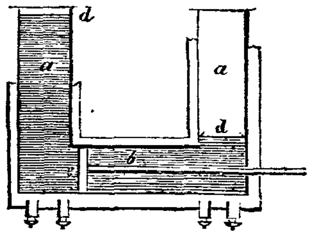
two cylinders of equal capacity, communicating at the lower part by a pipe, or passage C. These cylinders contain a quantity of oil, mercury, or other fluid, (which will not rise in vapour at the temperature to which it is to be exposed,) sufficient to fill the base of one cylinder, and nearly the whole of the other cylinder. Within the cylinder B is a piston exposed above to the pressure of the atmosphere; it has a piston rod, and is packed in the usual manner. In the other cylinder A is a thin metallic dish D floating freely upon the surface of the oil, or other fluid, before-mentioned. This latter cylinder has a top, perfectly air-tight, fastened down upon it, and through a stuffing-box in the centre of the top, passes a tube E terminating within the cylinder in a small nozzle, pierced with numerous small holes. In the cover of the cylinder is a flap-valve G, which is opened by a rod H striking it; the valve is kept up to its seat by a crane neck-spring above it; the valve-rod works through an air-

tight stuffing-box I; a safety-valve K is placed on the top of the cylinder. In the piston is an orifice fitted with a plug, by means of which the height of the fluid above the piston (it should always be kept a little above the piston) may be regulated; and at N is a cock, by which the fluid may be withdrawn from the cylinders. The cylinders, and the fluid contained therein, are heated by a sufficient number of argand lamps placed beneath them; and the cylinder A, and the lower part of the cylinder B, are surrounded by a casing, leaving a small space between them, so as to confine and carry the heated air entirely around them. On the top of the casing is a chimney P provided with a register Q, the better to regulate the heat of the air within the casing. By means of a small force-pump R, which is worked by the engine, a small quantity of alcohol is drawn from the condenser, and thrown suddenly through the pipe E on to the floating-dish D, which, being previously heated by the oil, or other fluid medium, on which it floats quickly, converts the alcohol into vapour, which, pressing upon the dish, and the oil on which it floats, forces the oil through the horizontal passage, and raises the piston to its highest point of elevation. The valve in the cylinder A being now opened, the vapour escapes by a tube S into a separate vessel, and is there condensed; the piston then descends by the pressure of the atmosphere, and the dish D is carried again to the top of the vapour cylinder A. The tube S is divided in the middle by a flat ring *a* of wood, cork, or other non-conducting substance, making an air-tight joint, and is inserted into a circular tube, or hollow ring V V, from which a number of small thin copper pipes U U descend. The lower ends of these pipes are inserted into another vessel W, which forms a reservoir for the vapour when condensed. The liquid formed by the condensation of the vapour, may be drawn off by the pipe and cock *d*. The outer and upper part of the condenser, has upon it a circular open basin X, which is kept supplied with water by a pump, or any convenient means. The small tubes U are each wrapt round with flannel, or other porous substance of like nature, the upper end of which hangs over the bason X into the water; and, acting like a syphon, conducts the water over the surface of the tubes U, down into a vessel Y below them. Within the circle, formed by the small tubes, is a fanner kept in rapid motion by the engine, by which means a stream of air is thrown upon the wet flannel, and the heat is, consequently, more rapidly extracted from the condenser. Previously to setting the engine to work, it is necessary to withdraw the air from the vapour cylinder and condenser, which is done by means of an exhausting pump or syringe, applied at *c*, to a pipe with a stop-cock *b* fitted on the top of the condenser. The liquid to be converted into vapour for working the engine, is introduced into the reservoir at the bottom of the condenser, through a tube *e* closed by a screw cap *f*. *Fig*. 2, shows a method of affecting the condensation by injection. The pipe *s* conveys the vapour from the vapour cylinder into the condenser *g*, which is formed of copper as thin as the pressure will admit of, and which contains a portion of alcohol, which may be introduced by the tube *e* as before, or by a funnel *o* and a stop-cock *p* on the top of *g*. A lifting pump *h* is put in motion by the engine, at the same time that the valve G (in *Fig*. 1) is opened, and the pump withdrawing a quantity of the alcohol from the lower part of the condenser *g*, injects it into the same vessel at the top, after passing it through a pipe or worm *i*, the end of which *k* being pierced with

Fig. 2.



many small holes, the liquid is dispersed throughout the vessel *g*, and condensing the vapour therein, falls with it to the bottom. Part of this liquid is again thrown into the vapour cylinder by the pump R, to be converted into vapour, as before described; and part of it is again employed to condense the vapour, as last mentioned. The condenser *g* and the tubes connected therewith, are placed in a cistern which is kept constantly full of cold water. The engine above described acts [illegible] nosphere, which also effects the return stroke of the p[illegible] presents an outline of an arrangement for avoiding this, and producing a double action. *a a* are the vapour vessels; *b* is the piston cylinder; *c* the piston working horizontally. The arrangement of the lamps, injecting tubes, &c. is upon the same principle as before. The vapour is alternately generated with the two vessels *a a*, and withdrawn from them, and acts upon the piston through the medium of the oil or other fluid, upon which, or upon the thin copper floats *d d*, the small quantity of fluid to be evaporated is injected, as before described. The patentee states that æther or essential oils might be substituted for alcohol, although he considers the latter preferable upon the whole, as it is more readily and effectually condensed. We have seen an alcoholic engine, intended for a 24-horse power, in occasional operation at the Iron Works at Rotherhithe, where the patentee perseveringly continues his experimental efforts on the great scale.



ALE. The name given to a species of malt liquor. See Beer.

ALEMBIC. The name formerly given to a common distillatory apparatus, now termed a *still*. See Alcohol and Distillation.

ALKALI. The term is derived from an Arabic word *kali*, the name of a plant containing an alkali. The alkalies possess these general properties in their pure state. They are caustic and acrid to the taste. They dissolve animal matter, and form a saponaceous compound with oils or fat. They combine with acids in definite proportions; the respective properties of each are destroyed, and a neutral salt is the result. On this account, they precipitate most metals from their acid solutions. They change most of the vegetable blues to green, and restore the colour of a vegetable blue reddened by an acid. They combine with water in any proportion. The most important of the alkalies in commerce and in the arts, are potash, soda, and ammonia. The two former of these are generally called the fixed alkalies, and the latter, the volatile. Some of the earths possess powerful alkaline properties, and have, therefore, by some writers in chemistry, been classed with the alkalies: these are lime, magnesia, barytes, and strontites. Many vegetables also contain matter decidedly alkaline; such as morphia, hyosciama, strychnia, &c. The properties and uses of these bodies, will be found under their respective heads.

ALKALIMETER. An instrument for ascertaining the strength of alkalies. The best, perhaps, is a tube graduated into a number of equal parts. Acid of a known specific gravity, diluted with water, and coloured with infusion of litmus, is poured in until a given number of parts is occupied. The alkali to be tried is accurately weighed, and gradually added to the dilute acid, until the original blue of the litmus, reddened by the acid, is restored. The relative quantity of an alkali requisite to neutralize a given portion of acid of uniform strength, is a test of its strength.

ALKANET, or Bugloss. A genus of the Monogynia order, belonging to the Pentandria class of plants. It is found chiefly in the warmer regions of the continent; that which grows in England is inferior in the colouring power of its roots, for which the plant is chiefly valuable. The greatest quantity is raised in France, from whence it is principally obtained. If the root of this plant is digested in oil, alcohol, or unctuous matter, a deep red colour is extracted, which is extensively employed in colouring various unguents, and also in staining mahogany and marble. The colouring matter exists in the bark of

the plant; and as the roots contain most bark, a greater quantity of colouring matter is extracted from them than from the other parts.

ALLOY. A combination of two or more metals. The term is sometimes employed to denote the inferior metal combined with gold or silver. Thus it is said the standard gold of jewellers is 18 carats of gold and 6 of alloy, whatever metal the alloy may be. When metals are combined either by fusion or cementation, the alloy formed generally possesses properties and characters very different from those of the respective components. The density is sometimes greater, sometimes less; the fusing point in some cases is considerably lower than the mean. Elasticity is sometimes communicated, sometimes destroyed; and the malleability and ductility of the alloy seldom correspond with those of the metals forming it. These important changes would lead to the inference, that alloys are chemical combinations, and not mechanical mixtures; but there are many objections to this supposition, the most important of which are, that metals may be combined in any proportions, and that they may be separated by the process called eliquation, if there is a great difference in the respective temperature of their fusing points. Thus, silver and lead may be separated from copper by heat, the copper requiring a higher temperature for its fusion than the other two metals combined; and an alloy containing a volatile metal, as mercury, or zinc, may be decomposed by a strong heat, the fixed metal remaining when the more volatile is expelled. In many cases, a very small proportion of one metal is sufficient to change the most important characters of another. A quarter of a grain of lead will render an ounce of gold perfectly brittle, although neither gold nor lead are brittle metals. If a crucible containing arsenic be placed in the same fire with a crucible containing gold, the fumes of the arsenic will render the gold brittle. Some of the changes thus produced are of the utmost importance in the arts, as many of the alloys are far more valuable on account of the newly-acquired properties, than any of the simple metals. Gold and silver, in their pure state, would be totally unfit for the useful purposes to which they are applied, if they were unalloyed, on account of their softness. Even the standard current coin of the realm is alloyed, to render it hard, otherwise the impression would be speedily effaced, and the coin, by abrasion, would soon become deficient in weight. Pure copper would be unfit for many of the purposes to which it is so extensively applied in the arts, if it were not alloyed by some metal to give it hardness; and it is singular that the metals employed for this purpose are all soft metals. Brass, bell-metal, gun-metal, &c. are all alloys of copper with soft metals. Some metals which will not combine together immediately, may be united by the intervention of a third. Thus, mercury will not combine directly with iron; but if zinc or tin is first added to the iron, an amalgam may be formed of it with mercury. It may here be observed, that when mercury is united to any other metal, the compound is called an amalgam. In order to make a perfect alloy, a very intimate admixture, by mechanical agitation, should be effected while the metals are in the fluid state. They should, therefore, be either constantly stirred with an infusible rod, or repeatedly poured from one hot crucible to another. Mr. Hatchett found that the lower end of a bar of standard gold was of inferior specific gravity and value to the upper extremity, which would be formed by the last portions of the metal in the crucible. The surface of metals, also, should be carefully defended, while in the fluid state, from the action of the atmosphere, by a stratum of wax, pitch, or resin, if the fusing point be low; or by a layer of salt, pounded glass, borax, &c, if it be high. In this article we shall merely give a brief account of the nature and composition of the most important alloys, and their respective uses. Where the mode of manufacture is complicated, and requires peculiar processes, we shall more fully describe them under their several heads.

Brass is composed of variable proportions of zinc and copper, according to the use for which it is required. In general, about 9 parts of zinc are added to 16 of copper when melted. The best brass is not made by the direct combination of the two fluid metals, but by the process called cementation (See Cementation). The vapour of the zinc ore by this mode combines more intimately with the copper.

Manheim Gold.—Three parts copper, 1 part zinc, and a small quantity of tin If these metals are pure, and are melted in a covered crucible containing charcoal, the alloy bears so close a resemblance to gold as to deceive very skilful persons.

Tombac, or *White Copper,* is formed of variable proportions of copper, arsenic, and tin.

Pinchbeck.—Five oz. pure copper, and 1 oz. zinc. The copper must be first melted before the zinc is added.

Prince's Metal is made of from 2 to 3 parts of copper, and 1 of zinc; or of common brass, with an extra portion of zinc.

Bell Metal.—Six to 10 parts copper, and 2 parts zinc. For small bells, a little zinc is added, and sometimes silver.

Tutania, or *Britannia Metal.*—Four oz. plate brass, and 4 oz. tin; when fused, add 4 oz. bismuth, and 4 oz. antimony. This composition is added at discretion to melted tin.

German Tutania.—Two drms. copper, 1 oz. antimony, and 12 oz. tin.

Spanish Tutania.—Eight oz. scrap iron, or steel, 1 lb. antimony, and 3 oz. nitre. The iron or steel must be heated to whiteness, and the antimony and nitre added in small portions. Two oz. of this compound are sufficient to harden 1 lb. of tin.

Queen's Metal.—Four and a half lbs. tin, ½ lb. bismuth, ½ lb. antimony, and ½ lb. lead. Or, 100 lbs. tin, 8 lbs. antimony, 1 lb. bismuth, and 4 lbs. copper. This alloy is used for making tea-pots, and other vessels, which imitate silver.

Red Tombac.—Five and a half lbs. of copper, and ½ lb. zinc. The copper must be fused in a crucible before the zinc is added. This alloy is of a red colour, and possesses greater durability than copper.

White Metal.—Ten oz. lead, 6 oz. bismuth, and 4 drms. antimony. Or, 2 lbs. antimony, 8 oz. brass, and 10 oz. tin.

Gun Metal.—One hundred and twelve lbs. Bristol brass, 14 lbs. zinc, and 7 lbs. block tin. Or, 9 lbs. copper, and 1 lb. tin. Lead was formerly used in this alloy to facilitate the casting, but at the battle of Prague it was found that some of the pieces of ordnance formed of this metal were actually melted by the frequency of firing.

Blanched Copper.—Eight oz. copper, and ½ oz. neutral arsenical salt, fused together under a flux of calcined borax and pounded glass, to which charcoal powder is added.

Specula Metal.—Seven lbs. copper, 3 lbs. zinc, and 4 lbs. tin. These metals form an alloy of a light yellow colour, possessing much lustre.

Metal for Flute Key Valves.—Four oz. lead, and 2 oz. antimony.

Printing Types.—Ten lbs. lead, and 2 oz. antimony. The antimony is added while the lead is in a state of fusion. The antimony gives hardness to the lead, and prevents its contraction when cooling. Some manufacturers employ different proportions of these metals, and some add copper or brass.

Small Type Metal.—Nine lbs. lead, 2 lbs. antimony, and 1 lb. bismuth. The antimony and bismuth are added when the lead is melted. This alloy expands in cooling; the mould is, therefore, entirely filled when the metal is cold, and no blemish is found in the letters. Stereotype plates are formed of this alloy. Some manufacturers employ tin instead of bismuth.

Common Pewter.—Seven lbs. tin, 1 lb. lead, 6 oz. copper, and 2 oz. zinc. The copper must be first melted before the other metals are added.

Best Pewter.—One hundred parts tin, and 17 parts antimony.

Hard Pewter.—Twelve lbs. tin, 1 lb. antimony, and 4 oz. copper.

Common Solder.—Two lbs. lead, and 1 lb. tin.

Soft Solder.—Two lbs. tin, and 1 lb. lead.

Solder for Steel Joints.—Nineteen dwts. fine silver, 1 dwt. copper, and 2 dwts. brass.

Silver Solder for Jewellers.—Nineteen dwts. fine silver, 1 dwt. copper, and 10 dwts. brass.

Silver Solder for Plating.—Ten dwts. brass, and 1 oz. pure silver.

Gold Solder.—Twelve dwts. pure gold, 2 dwts. pure silver, and 4 dwts. copper.

Bronze.—Seven lbs. copper, 3 lbs. zinc, and 2 lbs. tin. The copper must be melted before the other metals are added.

Mock Platinum.—Eight oz. brass, and 5 oz. zinc.

Alloy of Platinum with Gold.—Fifteen parts pure gold, and 1 part platinum. The gold must be melted before the platinum is added. This alloy is whiter than gold. Platinum has the singular property of depriving gold of its peculiar colour; if ten parts of gold are combined with only one of platinum, the alloy will appear of the colour of platinum. There is another remarkable property attending this alloy of gold and platinum, that it is soluble in nitric acid, which does not act upon either of the metals in a separate state.

Ring Gold.—Six dwts. 12 grs. pure copper, 3 dwts. 16 grs. fine silver, and 1 oz. 5 dwts. pure gold. Jeweller's gold is made of variable proportions of pure gold and copper, and sometimes of silver.

Imitation of Silver.—One lb. copper, and $\frac{3}{4}$ oz. tin. This alloy will be of a deeper colour than silver, but in other respects it is very similar.

Alloy of Platinum with Steel.—Platinum although the most infusible of metals, when in contact with steel melts at a comparatively low temperature, and combines with it in any proportion. This alloy does not rust or tarnish by exposure to a moist atmosphere, for many months. The alloy is malleable, and is well adapted for instruments which would be injured by slight oxidation, as mirrors for dentists, &c. The best proportions do not yet appear to be known; but it appears that if much platinum be used, the alloy has a damask or wavy appearance. Steel for cutting instruments is much improved by even $\frac{1}{500}$th of platinum.

Alloy of Silver and Steel.—Steel 500 parts, and silver 1 part. If a large proportion of silver is employed, the compound appears to be a mechanical mixture only. The silver is distinctly seen in fibres mixed with the steel, and the alloy is subject to voltaic action. When the proportion does not exceed $\frac{1}{500}$, the compound appears to be a chemical union; the steel is rendered much harder, forges remarkably well, and is infinitely superior to the best cast steel for cutting instruments, &c.

Alloy of Steel with Rhodium.—If from 1 to 2 per cent. of rhodium be combined with steel, the alloy possesses great hardness, with sufficient tenacity to prevent cracking, either in forging or hardening. This alloy requires to be heated about 73° Fahr. above the best English cast steel in tempering. It is superior to that metal; but the scarcity of rhodium will prevent the extensive use of this valuable compound.

Fusible Alloys.—Four oz. bismuth, $2\frac{1}{2}$ oz. lead, and $1\frac{1}{2}$ oz. tin. Melt the lead first, and then add the other metals. This alloy will melt in boiling water, although the melting temperature of the several components is much higher; viz. lead, 612°; bismuth, 476°; tin, 442°.

ALMOND. The well-known kernel of certain fruit trees, of which there is great variety. Almonds contain a considerable quantity of oil, on which account they are chiefly valuable. As an article of food, they possess little nutritious matter, and if taken immoderately, are indigestible, and even poisonous, on account of the prussic acid they contain. Bitter almonds yield a greater quantity of this poison than the sweet; they are therefore poisonous to some birds and small animals. Water distilled from almonds and other kernels, is found to be destructive of human life. Noyeau and other cordials flavoured by these substances, contain much of the bitter principle, or prussic acid. The oil of almonds may be extracted by simple pressure; if they are heated, a greater quantity is obtained. The oil from the bitter kernel is as tasteless as that from the sweet; the bitter principle is soluble in, and may be extracted by, water. Sweet almonds are extensively employed in medicine in the form of emulsion. They are skinned, and triturated in a mortar with a small quantity of water. After standing a short time, a thick cream separates, which will render many resinous substances mixible in water. The almond emulsion is generally combined with gum or sugar.

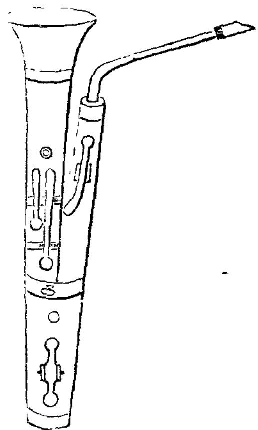
ALOES. The aloe is a plant of the Monogynia order, belonging to the Hexandria class. The medical substance called aloes, is the inspissated juice

of the plant. There are three sorts of this, viz. socotrina, hepatica, and caballina. The first of these, which is considered the best, comes from the island Socotora, whence its name. It is of a glossy appearance, and in a slight degree pellucid; if reduced to powder, it is of a bright golden colour. The hepatica is so called from its liver colour, and is chiefly brought from Barbadoes in large gourd shells. Its taste is intensely bitter and nauseous. The caballina is principally used as a medicine for horses, from which circumstance it derives this appellation. It is coarser and more impure than the others, and has a rank strong smell. The three varieties have, however, all been obtained from the same plant, at Morviedro, in Spain. The first, from the liquid which flows spontaneously from the incised leaf; the second, from the juice afterwards extracted by pressure; and the third, by mixing the expressed juice with the dregs of the former. Pure aloes are nearly soluble in water and in alcohol. They are powerfully aperient, and in large doses produce much irritation: small doses are tonic and aperient.

ALTITUDE. The height of any place or thing; one of the three dimensions of solid bodies; elevation of the celestial bodies, &c. In geometry, the altitude of a figure, or a solid, is the perpendicular distance between its vertex and base. The altitude of buildings, trees, &c. may be measured like that of geometrical solids, from the base to the vertex, but the altitude of lofty mountains or elevated plains is reckoned from the level of the ocean. There are various means for determining altitudes, such as geometrical construction; by observation of shadows; by trigonometrical calculation; and by the use of the barometer. For an account of the various instruments employed as quadrants, sextants, theodolites, barometers, &c., with the methods of applying them, consult their respective names. The altitude of terrestrial bodies may be either accessible or inaccessible. When the object viewed is accessible, and on the same horizontal plane as the observer stands, its altitude may be found in the following way: Provide two deal rods, one longer than the other; fix the shorter one vertically in the ground, and having placed your eye at its top, let an assistant move towards the tower in a direct line, till the top of the second rod is seen on a line with the summit of the object whose altitude is required. Next measure the distance between the two rods, and also between the shorter rod and the tower. Then say, as the distance between the two rods is to the distance of the shorter rod from the tower, so is the difference in length of the rods to the difference between the height of the tower and the shorter rod. Hence, if to this difference we add the length of the shorter rod, it will give the altitude required. The result may, however, be more conveniently, as well as more accurately obtained, by means of a quadrant, or other instrument to measure angles, in the following manner. Measure the distance of the observer's place from the foot of the tower, and take the angular elevation by means of the quadrant; then say, as the cosine of the observed angle is to the measured distance, so is the sine of the observed angle to the altitude required. Altitude, in astronomy, signifies the angular distance of a celestial body from the horizon, measured on a vertical circle. The altitude is either true or apparent, accordingly as it is measured from the rational or the sensible horizon. The observed or apparent altitude varies from the true on two accounts. First, the body is seen from the surface of the earth, instead of from the centre, which causes it to appear lower than its true place, by a quantity which is denominated the horizontal parallax. Secondly, the rays of light by which the body is perceived, are refracted by the terrestrial atmosphere, and, consequently, it appears higher than it otherwise would. To obtain the true altitude, therefore, of a celestial body, we must add the parallactic angle to the apparent altitude, and from the sum subtract the refraction. The fixed stars, from their great distances, have no sensible parallax, and hence the preceding remark applies only partially to them. But the difference between the true and apparent altitude of the moon, is, from its proximity to us, about 52°. Altitude of the eye, in perspective, is the height of that point in the perspective plane which would be made by a right line drawn from the eye and cutting the plane perpendicularly.

ALTO FAGOTTA, or *Octave Fagotta*. A new musical instrument. It is

very sonorous, the upper notes approximating closely to those of a horn, though much softer; the lower notes blending very harmoniously with those of the voice, piano-forte, &c. The compass of the instrument is three octaves, commencing with the C in the second space bass clef, or four notes lower than the fourth string of the violin, continuing to the C the second ledger line above the treble stave, with their intermediate semitones. It is played with a reed and mouth-piece similar to a clarionet. The annexed representation, although like the small bassoon, differs materially in its tone and compass. There are three keys and key-holes on the opposite side to that delineated.



ALUDEL. The recipient of vapourizing substances subjected to the operation of heat. They are generally of earthenware, and of various forms and size. Sometimes tubes are employed as aludels, and sometimes vessels of large capacity, according to the nature of the substance which is to be condensed in them. The process of condensing the product is much facilitated by keeping the aludel constantly cool by wet cloths or a stream of water.

ALUMINA. A primitive earth existing in great abundance in clays, earths, ochres, rocks, &c. Soils containing much of this substance are called argillaceous. It is found in a state of great purity in many precious gems, as the sapphire, topaz, emerald, garnet, beryl, &c. When pure, it is of a white colour, pulverulent, and soft to the touch. It adheres to the tongue, but is tasteless. It is insoluble in water, but is readily dissolved by acids, and also by caustic, potash, or soda. If moistened with water, a very ductile and tenacious paste is formed, which, by heating, becomes exceedingly hard, and is, therefore, extensively employed in the manufacture of porcelain, earthenware, and all kinds of pottery. Bricks, tiles, crucibles, and stone ware, contain large quantities of alumina. It is infusible, *per se*, in the strongest heat of a furnace, but small quantities may be fused by the oxy-hydrogen blow-pipe. If mixed, however, with certain proportions of lime and silica, it fuses readily. Pure alumina may be obtained easily from the triple salt, containing ammonia instead of potash, by heating it intensely. The acid and the alkali are dissipated by the heat. and the pure earth remains. It is usually procured by adding a small quantity of solution of bicarbonate of potash to a solution of common alum, which precipitates the iron contained generally in that salt. The filtered liquid is then to be added to the liquid ammonia, which combines with part of the sulphuric acid of the alum, and precipitates the earth in a spongy mass. This must be washed frequently in distilled water, and then heated to dryness. According to the experiments of Sir H. Davy, it appears, that, like the other earths, alumina is a metallic oxide. By passing potassium in vapour over alumina heated to whiteness, a great part of the vapourized metal was converted into the alkali potash :—a decisive proof that alumina contains oxygen. By treating the chloride of aluminum with potassium, a grey powder is obtained, which, by burnishing, acquires metallic lustre. This powder burns with much splendour if heated to redness, and is converted to alumina by absorption of oxygen. The metallic base is called aluminum; and it is found that 100 parts combine with 8 of oxygen. Alumina has the unusual property of contracting by heat, and in pretty exact proportion with the intensity applied. On this property the ingenious Mr. Wedgewood constructed his pyrometer for estimating very high temperatures. See PYROMETER. This useful earth has a powerful affinity for colouring matter, and also for greasy substances. Fuller's earth and pipe-clay owe their useful properties to the large quantities of alumina they contain.

ALUM, a triple salt of great importance in the arts, is composed of sulphuric acid, alumina, and potash. It is sometimes found native, but only in small quantities, and is artificially manufactured, chiefly from the mineral called alum-

slate. This is found in great abundance in the north-east district of Yorkshire, more particularly between Whitby and Stockton. In the reign of Queen Elizabeth, Sir Thomas Chaloner established a manufactory of alum at Gisborough, in Yorkshire, and engaged several expert workmen, acquainted with the mode of manufacture, from the dominions of his Holiness the Pope, who fulminated bulls and anathemas against him and them in vain. The alum-slate is also found in abundance at Beckel, in Normandy. There are other aluminous minerals from which alum may be obtained; but none appear so well adapted, nor so plentiful, as the alum-slate, or aluminous schist. The mineral from which alum is manufactured, is broken into small pieces, and placed on a bed of fuel, until it is about 4 feet high. The fuel is then ignited, and as the calcination proceeds, more of the mineral is added from time to time, until an enormous pile, sometimes equal in area to 200 square feet at the base, is formed The combustion proceeds so rapidly, that it is necessary to prevent access of air, by plastering the crevices with small schist (alum-slate,) made into a lute with water. It requires about 130 tons of the mineral to produce one ton of alum. When the calcination is effected, the residue is digested in pits containing large quantities of water. The liquid is withdrawn by pumps, and added to fresh calcined ore. This is repeated until its spec. grav. becomes about 1.15. This saturated liquor is sometimes placed in pits, to deposit sulphate of lime, and other earthy matter, which may contaminate it, and sometimes boiled to produce the same effect. The purified liquid is then concentrated at a boiling heat, in large sloping leaden pans. This is then removed to a *settling* cistern, and a solution of muriate of potash, or the impure alkali of the soap-maker, is added to it. The quantity necessary is ascertained by experiment with a small portion in a basin. The alkaline solution reduces the spec. grav. from 1.4 or 1.5 to 1.35. The quantity of alkali required is, therefore, easily ascertained by an hydrometer. If the spec. grav. of the liquid be more than 1.35, it does not yield crystals, but a solid magma resembling grease, and it becomes necessary to reduce it and re-crystallize. Urine is sometimes added for this purpose; it is crystallized in the usual manner by slow evaporation. These crystals are purified by washing and boiling in a leaden vessel. The saturated solution is then poured into casks, and in about a fortnight the casks are unhooped and taken to pieces, the alum remaining in a solid mass. This last process is called roching. It is calculated that 22 tons of muriate of potash, or 31 tons of the black ashes of the soap boiler, or 73 of kelp, are necessary to make 100 tons of alum. Ammonia may be employed instead of potash, but it is more expensive. The impure sulphate of soda formed in the manufacture of aqua fortis, may be economically employed in the manufacture of alum, as it contains two out of the three ingredients necessary to its formation. Th celebrated Chaptal manufactured alum artificially in France to a great extent. A chamber of very large dimensions was constructed of masonry, and floored with brick; the bricks being cemented with a composition of pitch, wax, and turpentine. The roof was of timber, but the planks were closely grooved into each other, no nails being employed. Lastly, the whole of the interior was covered with a thick coating of the above-mentioned cement, applied as hot as possible. The purest and whitest clay is then, after calcination, strewn on the floor, and sulphur burned in the chamber. By this process sulphuric acid is formed, which in a few days saturates the alumina of the clay, converting it into sulphate of alumina. This is known by the efflorescence that takes place. The salt is then removed and exposed to the air, that the acid may penetrate more effectually the alumina. It is then lixiviated, treated with potash, and crystallized as before described. One of the most ancient manufactories of alum was at Roche, in Lyria, whence is derived the term Roche-alum.

According to the analysis of Berzelius alum consists of

Sulphuric acid	34.33
Alumina	10.86
Potash	9.81
Water	45.00
	100.00

Or, Sulphate of alumina	36.85
Sulphate of Potash	18.15
Water	45.00
	100.00

The taste of alum is rather sweet, but astringent. It is a super-sulphate, and reddens the vegetable blues. The spec. grav. is about 1.71. It is soluble in 16 parts of water at 60°, and in ¾ths of its weight of boiling water. By long exposure to air, the surface effloresces, but the interior will remain a long time unchanged. A moderate degree of heat expels its water of crystallization, but an intense heat decomposes it, by separating a great part of its acid. The alum of commerce generally contains much impure matter, particularly if kelp or urine has been used in the manufacture. The sulphate of iron is, perhaps, the most injurious foreign ingredient in its composition; this may be detected by ferro-prussiate of potash. Alum is of great use and importance in many processes of the arts. It is very extensively employed in dyeing, as a mordant. Most of the vegetable colours employed in dyeing have no affinity for the material intended to be dyed. In most of these cases alum is employed as the intermediate medium by which the colouring matter may be fixed, as it has an affinity both for the material and the colouring matter. An acetate of alumina is frequently employed by the dyer, instead of the ordinary sulphate. The acetate does not act so corrosively on delicate articles as the common alum, and its affinity for some colours is greater. It is easily prepared by the double decomposition of a solution of the sulphate of alumina and potash, and a solution of the acetate of lead. When these two solutions are mixed together, the sulphuric acid of the alum combines with the lead, forming an insoluble precipitate, which is sulphate of lead, while the liberated acetic acid unites with the alumina and potash, forming the required acetate, which is separated by filtration from the solid substance. If paper, linen, or wood, be soaked in a solution of alum, it is rendered nearly incombustible, and less liable to be affected by moisture. Paper thus prepared is advantageously employed in wrapping gunpowder and is also useful in whitening silver. Alum has the property of hardening tallow, for which purpose it has been sometimes advantageously employed. It is used with much success in the preparation of skins for tanning, giving them firmness after they have become flaccid by immersion in the lime pits. Turbid water is rendered limpid and transparent by the addition of a small quantity of alum in solution; its purity, however, is by no means promoted by the process. It is usefully combined with the salt by which cod fish are cured, as it prevents a deliquescence which would otherwise take place. It is used in the manufacture of London bread rather extensively, as it enables the baker to employ flour of inferior quality; the alum promotes a white colour and closeness of texture in the bread,—qualities much [illegible] y generally indicate impurity. It improves the colour of t [illegible] Prussian blue, and is extensively employed in the preparation of that article. In medicine it is administered as an astringent and tonic, and also as a collyrium. Alum, deprived by heat of its water of crystallization, which, in medicine, is called *alumen ustum* (burnt alum), has been greatly extolled as a remedy in cases of colic, and some other disorders. A remarkable substance, called Homberg's pyrophorus, is prepared from alum. Equal parts of alum and brown sugar are melted over a clear fire, and stirred constantly until they become dry. When cold the mixture is finely powdered, and placed in a phial coated with clay, having an open glass tube luted into its neck. This is to be intensely heated in a crucible containing sand, when gas will issue from the tube, which may be inflamed. When this ceases to come over, the crucible is removed, and the tube stopped by moistened clay until the bottle is sufficiently cold to be corked. The substance thus formed is a black and light powder, which takes fire when poured from the bottle into the air. If poured into oxygen gas a more vivid combustion takes place.

AMADOU. This substance is, perhaps, better known by the familiar appel

lation of German tinder, and is chiefly employed in procuring a light speedily, as it ignites immediately with a feeble spark from the flint and steel, or by condensation of atmospheric air, and burns with slow and smouldering heat for a considerable time. It is formed of a spongy excrescence, or mushroom, found on old trees, particularly the oak, ash, and fir. This is washed and boiled in fair water, and afterwards beaten by a mallet until it resembles very spongy leather; it is then soaked in a saturated solution of saltpetre, and dried in an oven. A good substitute for this may be formed of coarse brown paper, soaked in the solution of saltpetre, and dried in an oven.

AMALGAM. A combination of mercury with any other metal.

AMBER. A hard, solid, semi-transparent substance, found in several mines of Prussia, in a bed of argillaceous mineral. It is also found in Poland, France, Italy; on the shores of the Baltic and Mediterranean, in the neighbourhood of London, and in various other parts. It is generally considered to be of vegetable origin, and to be composed of bituminous vegetable matter in a state of congelation. The extraordinary property which amber possesses of attracting, when excited by friction, light bodies, such as feathers, bits of paper, pith, dust, &c., was known to Thales, the celebrated philosopher of Miletus, who flourished 600 years before the birth of Christ. The Greek term for amber is election; and from this word is derived the title of our modern science, electricity, the effect of excited amber in attracting light substances, being attributed to its elective powers. This mineral is found of various colours, but the most abundant is of a deep yellow or orange. When broken, the fracture is smooth and glossy, and it is susceptible of a beautiful polish. If gently rubbed, it emits a peculiar and agreeable odour. At a temperature of 550° Fahr. it melts, and its transparency is destroyed. It is insoluble in water; but alcohol, if highly rectified, extracts a small quantity of its colouring matter. Sulphuric acid will dissolve it, and it may be then precipitated by water. Pure caustic alkalies also dissolve it, and some of the essential oils. Various specimens of amber have been found containing portions of animal, vegetable, or mineral matter, imbedded in the mass. This fact seems to prove that it has once been in the fluid state. From the appearance of insect remains in amber, it would seem that they have attempted to escape from a viscid or congealing mass. In some, the legs, or wings, only, have been found, which seems to prove that the animal has been entangled in the viscid mass, and has left the fragile parts of the body in attempting to wade through it. Drops of water, leaves of plants, native gold, silver, and various other substances, have been found imbedded in amber. Dr. Girtanner promulgated a very ingenious opinion on the formation of amber, which appears plausible. He imagined that a species of ant called *formica rufa*, formed this substance by the deposition of their peculiar wax, or honey. These ants are found in immense numbers in the pine forests, where amber is obtained in the mineral state. The wax, although soft, hardens by immersion in salt water, and then bears a great resemblance to amber. Dr. Brewster, however, considers, from the optical properties of amber, that it is established beyond doubt, to be an indurated vegetable juice. By careful distillation, an empyreumatic oil, equal to one-third in weight of the amber, is obtained. This oil is brown and thick if a strong heat is applied, and requires re-distillation; but if the heat do not exceed 212, and water be employed, it is limpid and colourless. It is used in medicine as an antispasmodic. The spec. grav. of amber varies from 1.065 to 1.100. For its use in varnish-making, see Varnish.

AMBERGRIS, or Ambergrease. A solid, opake, fatty substance, found on the sea-coast, or sometimes floating on the sea, chiefly in the tropical regions. It is of various colours, but generally of a deep ash-coloured yellow. It is most frequently obtained in small fragments, but large masses, weighing from 100 to 180 lbs. have been found. It has frequently been discovered in the intestines of the spermaceti whale, and is supposed to be the cause, or the result of disease in the animal. Healthy fish, which void their excrements when they are hooked, seldom contain amber; but diseased fish, unable to perform this function when caught, generally yield it; and it is almost always found

in the fæces of the whale when dead and floating on the waters. There can be little doubt that this substance is *formed* in the intestines of the animal, not swallowed by it as some have supposed; for no large piece has yet been found in the whale, which does not contain the beaks of the Sepia octopodia, the common food of the spermaceti whale. When first obtained, ambergris has the fœtid smell peculiar to the fæces of the animal; but after a short exposure to the air and washing, its odour is fragrant, and is increased by heating. It is not a little extraordinary that Mr. Homberg obtained, by long digestion of human excrement, a substance which possessed, in a very intense degree, the perfect smell of ambergris. The spec. grav. of ambergris varies from 0.780 to 0.926. It melts at 144° Fahr. and at 212° Fahr. is volatilized in the form of a white vapour. If thrown on hot coals, it burns and is entirely dissipated. It is not soluble either in water or the acids. Ether, ammonia, and oil, dissolve it, but alcohol acts only on a portion, and is therefore useful in analyzing it. Caustic alkalies combine with it and form a soap. According to La Grange, it is composed of adipocere resin, benzoic acid, and coal. By later analysis it has been found that some specimens do not contain benzoic acid. The alcoholic solution is used in cosmetics, &c., to communicate its peculiar odour.

AMETHYST. A natural gem, of a violet colour and great brilliancy, as hard as the ruby or sapphire, from which some say it only differs in colour. The Asiatic are of a deep purple hue, and are deemed the most valuable. The German are violet. Some amethysts are, however, made colourless by art, when they are often mistaken for diamonds; the superior hardness of the latter will, however, enable any person to detect the imitation.

AMMONIA. A powerful alkali, sometimes called the volatile. In its pure state it is a gas transparent and colourless, and possessing all the mechanical properties of ordinary atmospheric air. Its smell is pungent and suffocating, and its taste extremely caustic. It extinguishes combustion, and immediately destroys animal life. One hundred cubic inches weigh 18.16 grs. Its spec. grav. is 0.5954. If the gas is passed through an ignited porcelain tube, containing iron, it is decomposed, and its volume doubled; it is then found to consist of 1½ volume of hydrogen, and ½ volume nitrogen, which are condensed into the bulk of one volume as ammoniacal gas. It is rapidly absorbed by cold water, which, when impregnated with gas, is called liquid ammonia, or spirits of hartshorn. At a temperature of 50, water absorbs about 670 times its volume of the gas, and its spec. grav. is reduced to 0.875. This liquid, by heating, parts with the ammoniacal gas, hence it is called the volatile alkali. The manufacture of liquid ammonia is a very important one. As this alkali is very extensively employed in medicine, chemistry, and the arts, we shall, therefore, briefly describe the process. Into a retort connected with a series of Woolfe's bottles, put two parts of slaked lime, mixed with one part of muriate of ammonia (sal ammoniac). The Woolfe's bottles must be filled with pure water, and if they are surrounded by cold water, frequently renewed; if by ice, a more highly saturated liquid will be obtained. The muriate of ammonia is decomposed by the lime, and the ammonia passes into the water in the bottles in the state of gas, where it is immediately absorbed. The addition of hot water, and application of moderate heat, ensure complete decomposition of the salt. The liquid ammonia may be obtained by a more direct process, but not so economically. The following mode is recommended by Mr. R. Phillips, as being superior to that recommended in the London Pharmacopœia. Pour half a pint of water on 9 oz. of well burnt lime, and when it has remained in a close vessel an hour, add 12 oz. of sal ammoniac, and 3½ pints of boiling water. Filter the solution when cool, and distil from it 20 fluid oz. This will have a spec. grav. of 0.954, which is as strong as it can be conveniently kept. The spec. grav. of liquid ammonia is a sure test of its strength. That above-mentioned will contain about 11 per cent. of ammonia. If the spec. grav. be .850, the liquid will contain about 35 per cent.; intermediate densities indicate intermediate proportions of ammonia. The muriate of ammonia, or sal ammoniac, from which the above-described liquid is obtained, was formerly brought from Egypt almost exclusively. In the neighbourhood of the temple of Jupiter

Ammon, were many inns for the accommodation of pilgrims and their camels. From the sublimed dung of these animals the salt was obtained, and its name was derived from the locality of its manufacture. In modern times, ammonia has been procured by the dry distillation of bones, horns, and other animal matters; and, more recently, from the waste liquor of the gas works, which contains large quantities of impure ammoniacal salts. The muriate of ammonia is employed in chemical analysis, in dyeing, and in tinning or soldering. It is the most delicate test for the presence of platinum, and is generally used by the chemist to precipitate that metal from its combinations in solution. There are many other valuable salts of ammonia, the most important of which are the nitrate and carbonate. The nitrate, when heated to 400° Fahr. is decomposed, and yields the nitrous oxide, or laughing gas, in abundance. It is also used in the preparation of frigorific mixtures; if mixed with an equal weight of water, the thermometer sinks above 30° Fahr. The carbonate is a useful chemical agent, and is used in medicine as a stimulant. This substance is the common smelling-salts of the shops. All the salts of ammonia are decomposed at a red heat. Chlorine decomposes liquid ammonia, or the gas, with great energy. If a bottle containing chlorine gas be brought in contact with the surface of liquid ammonia, the hydrogen of the latter substance combines with the chlorine, forming muriatic acid, which unites with another portion of ammonia, and nitrogen is left in the bottle. If this experiment be formed in a dark room, a flash of light will be seen at the moment of combination. If the mouth of a bottle containing chlorine gas be brought in contact with the mouth of another containing ammoniacal gas they combine with explosive violence, a flash and report accompany the action, and the bottles are sometimes broken.

AMMONIAC GUM is a concrete gummy-resinous juice. This gum has a nauseous sweetish taste, succeeded by a sensation of bitter, somewhat resembling galbanum, but more grateful. It is usually brought from the East Indies, in large masses composed of lumps, or tears; it acquires a yellowish appearance on exposure to the air. When chewed, it softens in the mouth, and becomes of a white colour. It may be partially dissolved in water, or in vinegar, with which it assumes the appearance of milk; but the resinous part, amounting to about one-half, subsides when suffered to rest. In medicine, it is prescribed for removing obstructions of the abdominal viscera; in hysterical complaints, and in long and obstinate colics, proceeding from viscid matter lodged in the intestines. Externally, it is used for the purpose of discussing indolent tumours; and, with a mixture of squill vinegar, forms a plaster sometimes successfully applied in the case of white swellings.

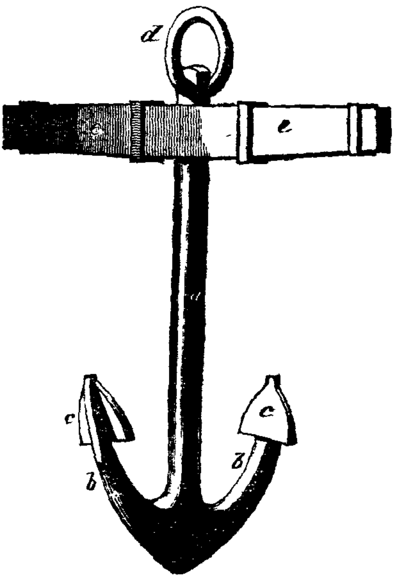
ANACARDIUM. The cashew-nut tree; a genus of plants of the class Enneandria, and order Monogynia. At one extremity of the fruit of this tree there is a flattish kidney-shaped nut, between which and the shell is a small quantity of liquor, which is useful for marking linen, being very black and durable.

ANACLASTIC GLASSES. A kind of sonorous glasses, chiefly made in Germany. They have the property of being flexible, and emitting a vehement noise by the human breath. The anaclastic glasses are a low kind of phials, with flat bellies, resembling inverted funnels, whose bottoms are very thin, scarcely surpassing the thickness of an onion-peel; this bottom is not quite flat, but a little convex. On applying the mouth to the orifice, and gently inspiring, or, as it were, sucking out the air, the bottom gives way with a tremendous crash, and the convex becomes concave. On the contrary, upon expiring or breathing gently into the orifice of the same glass, the bottom, with no less noise, bends back to its former place, and becomes gibbous as before.

ANACLASTICS. That part of Optics which considers the refraction of light, and is commonly called Dioptrics.

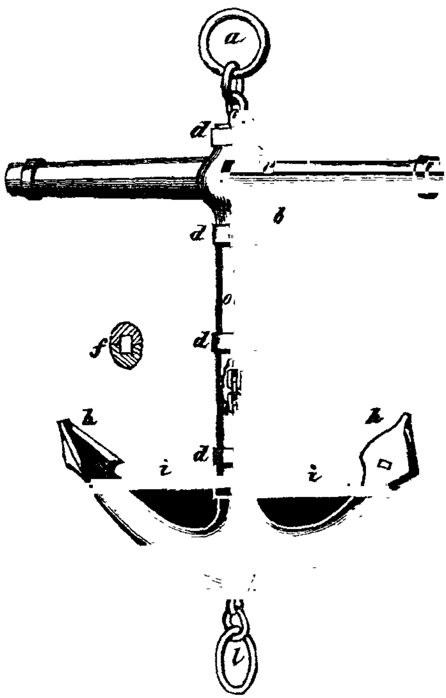
ANCHOR. A heavy curved instrument, used for retaining ships in a required position. The forms of anchors, and the materials of which they are made, are various. In many parts of the East Indies the lower part of the anchor is formed of a cross of a very strong and heavy kind of wood, the extremities of

which are made pointed. About the middle of each arm of the cross is inserted a long bar of the same wood, the upper ends of which converge to a point, and are secured either by ropes or an iron hoop, and the space between the bars is filled up with stones to make the anchors sink more deeply and readily. In Spain, and in the South Seas, anchors are sometimes formed of copper, but generally in Europe they are made of forged iron. Anchors may be divided into two classes—mooring anchors, and ships' anchors. Mooring anchors are those which are laid down for a permanency in docks and harbours, and are considerably heavier than ships' anchors, from which they differ in form, having sometimes but one arm, and sometimes, instead of arms, having at the extremity a heavy circular mass of iron and no stock; these latter are called mushroom anchors. The general form of ships' anchors is shewn in the annexed figure. *a* is a long bar of iron, called the shank, from the lower extremity of which branch two curved arms *b b* in opposite directions, and forming an angle of 60° each with the shank. Upon each arm, towards the end, is laid a thick triangular piece of iron *c c*, termed the *fluke*. In the upper end of the shank is an eye, through which passes a ring *d*, to which the cable is attached. The stock *e* is composed of two strong beams of wood, embracing the shank immediately below the ring, and secured together by iron hoops and treenails; the stock stands at right angles to the plane of the arms, and serves to guide the anchor in its descent, so as to cause one of the flukes to enter the ground. Ships are generally provided with three large anchors, named the best bower, the small, and the sheet anchor; a smaller anchor, termed the stream anchor; and another, still smaller, named the kedge, which latter has generally an iron stock passing through an eye in the shank, secured thereto by a key, or forelock, which admits of its being readily displaced: its principal use is in changing the position of a ship in harbour, and in an operation termed kedging. From the great mass of iron in large anchors (some weighing from 3 to 4 tons), the perfect forging of them becomes a matter of much difficulty; as from the great heat necessary to weld such masses, the iron is liable to become "burnt," as it is termed. Workmen also cannot always observe what is going on in the forge, where the iron is exposed to ignition from the blasts of the bellows, or to the presence of sulphur in quantity among the coals. When the welding of a large mass, like the shank of an anchor, is to be completed by the sledge hammer, the workmen are subjected to a scorching heat radiating therefrom, which renders it impossible to make a very close inspection, and the consequence frequently is, the beating up of cinders within the body of the iron. To this cause, and to burning, may be often attributed the breaking of anchors, followed too frequently by a distressing loss of lives and property. Many attempts have been made of late years to construct anchors not liable to these defects, by dividing the mass into separate parts, and by a more judicious arrangement. The following is the invention of Mr. Hawkes, a surveyor of shipping, in the Commercial-road, London.



Mr. Hawkes observes, "The anchors at present in use are made by forming

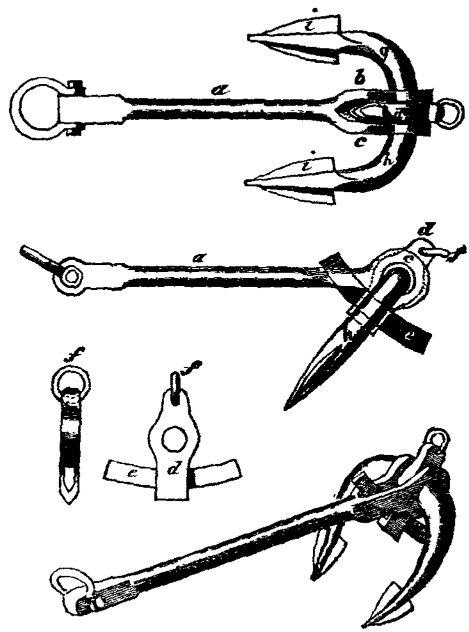
the shank and flukes separately; and by the rapid action of heavy hammers, they are united or welded into each other, and the cable is fastened to a ring passed through the shank sideways. The stocks, if of wood, are let or scored over each side, and bolted and hooped over the shank of the anchor; if of iron, the eye or hole for it is formed by punching a hole through the shank of the anchor; the palms are made separately, and welded on to the flukes. The improvement consists in making one fluke and half the shank in one length, and to bend them to the form required, and then hooping the two halves together. This method of making the anchor in separate parts, admits of the forming of a groove up the middle of the shank, for a chain to pass through, and of an eye of great strength for the reception of a wooden stock, which is also made in two pieces, and passed into the shank in reverse directions; these having iron shoulders abutting against the eye, are kept immovably in that position by being braced together with an iron hoop at each end. The construction is shown in the annexed engraving. *a* the cable ring; *b* the eye which holds the stock, made out of the whole substance of the shank, by bending each of the halves into a semicircle, in opposite directions. The anchor is shewn to be divided into two equal parts, by a line which passes down the middle of the shank, as at *o o*; *c* the wooden stock, made also in two equal parts (as before described), and firmly secured in their places by the hoops and shoulders; *dddd* are four strong hoops which bind the shank together; the upper one is made square, and the others circular; a portion of the shank is supposed to be removed, to exhibit the situation of the chain which passes up the centre, and is connected at the upper end to the cable ring, and at the lower end to the buoy ring. *f*, in the small separate figure, gives a transverse section of the shank of the anchor, showing it to be of an oval form,



the longest diameter of which is in a line with the flukes; this figure conferring upon it great strength to withstand the powerful strains to which an anchor is frequently exposed in that direction. *h h* are the palms, bolted to the respective flukes, each of which is connected in one piece with a brace *i i*, passing in opposite directions round the shank of the anchor, thereby strengthening the flukes in a great degree, and giving a collateral support to each half of the anchor *k* is a strong plate of iron bolted on to the crown; *l* the buoy ring."

An anchor, differing materially in form and construction from the ordinary, was invented by Mr. R. F. Hawkins, and is represented in the subjoined engravings. The shank of the anchor *a* is forked at the lower part or crown, into two parts or loops *b* and *c*, in each of which is formed a hole or eye; between the loops is a block of iron *d*, termed a crown piece, having a circular aperture to receive the arms, and a square aperture at right angles to the former, into which is screwed a stout bar of iron *e*, termed a toggle, projecting equally

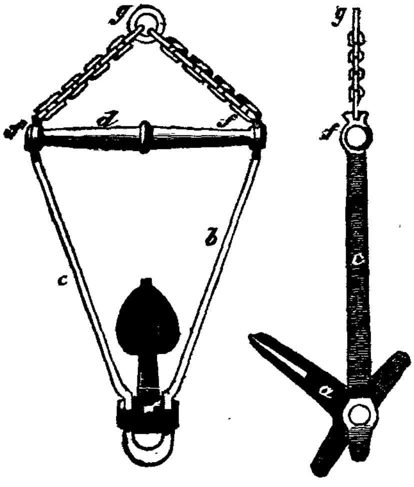
on each side of the crown piece; on the end of the crown piece, opposite to that in which is inserted the toggle, is a ring *f* for the buoy rope. The arms *g h* are formed in one piece, and before the palms *i i* are attached, one end of the arms must be passed through the eyes in the loops of the shanks, and through the eye of the crown piece; the palms are then to be put on, and must both



lie in the same plane; after which the arms are to be curved in the same plane with the palms. The crown piece is firmly keyed to the arms, and the toggle must be of such a length and form as to make it bear firmly against the fore part of the fork in the shank, so as to prevent the crown piece and arms from turning round upon it, and to retain them at an angle of 50° with the shank. When the anchor is let go, one end of the toggle will come in contact with the ground, which puts the flukes in a position to enter; and when the strain is upon the cable, that end of the toggle which is upwards comes in contact with the throat of the shank, and sets the anchor in the holding position, as shown in perspective at *Fig.* 3. The advantage of this mode of constructing anchors is, that both arms take the ground, and therefore the weight of metal may be diminished, and yet an equal, if not a greater, effect be obtained; also as there is no stock, and no projecting upper fluke, there is little risk of *fouling*, as it is termed; that is, of the cable entwining round the arms. The only objection which occurs to us, is the probability that, when at single anchor, it might not so readily turn in the ground at the turn of the tide, as the ordinary anchor, and therefore might be likely to trip; but for moorings we have no doubt that it would be found very effective.

An anchor upon a similar principle, but of a somewhat different construction, was invented by Mr. Soames, a front and side elevation of which is exhibited in the subjoined cuts. In this anchor there is but one fluke *a*, which is T shaped, and works on a pivot in a triangular frame, composed of the two sides *b* and *c*, forged in one piece, and a stay *d*, which serves as a stock; *f f* are loops, or eyes, for the reception of the chains that unite

the ring g, to which the cable is to be fastened. For general purposes, this anchor is, perhaps, preferable to the former, it being free from the objection we made to that one, as it admits of detaching the arm, which renders it more convenient to stow away; also, as the shank is formed in two parts, instead of one of equal area, they are more easily forged, soundly, and, consequently, less liable to breakage.

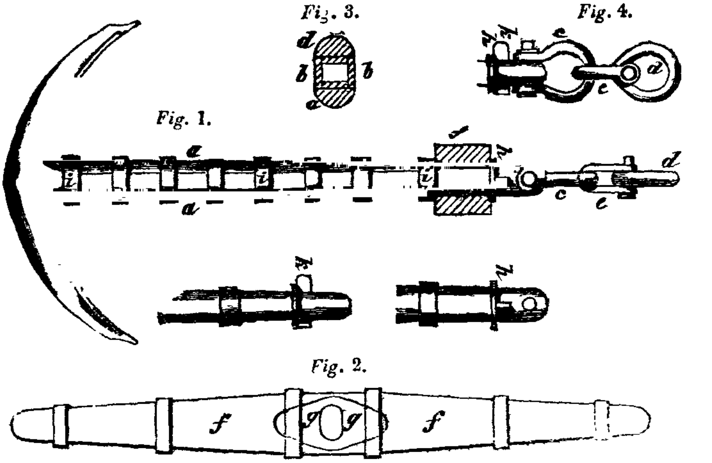


The anchor invented by Lieut. W. Rogers, R.N. is deserving of notice in this place. Its main peculiarity consists in its having a hollow shank, formed out of six bars of iron, of such a thickness as to insure the forging of them perfectly sound for anchors of the largest dimensions. The construction we shall describe with reference to the subjoined figures. *Fig.* 1 represents a side view of the anchor, and *Fig.* 2 a plan of the stock. The two principal pieces *a a* are bent so as to form a part of the arms or flukes; the other four are formed into a hollow tube *b b* (as shown in section at *Fig.* 3) for a centre-piece, and the whole

Fig. 3. *Fig.* 4.

Fig. 1.

Fig. 2.

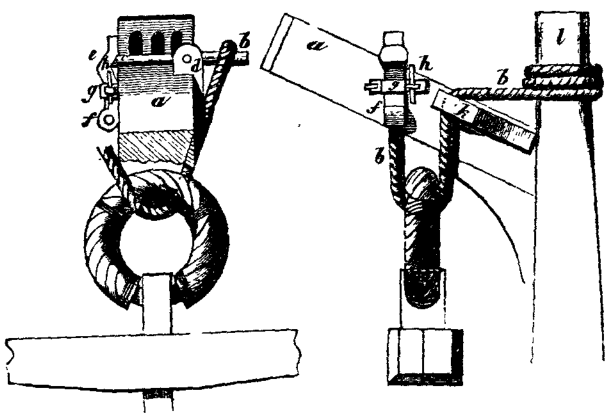


are firmly welded together at both ends of the shank. The intermediate parts are secured by strong hoops *i i*, so that every piece must bear its proportion of the entire strain. The patentee states, that so great is the strength thus obtained for the shank, that both arms have been broken off by the testing machine, without altering the shank in the least degree. On the 11th of June, 1829, an experiment was made at the Gateshead iron-works, in the presence of several respectable ship-owners, when the patent anchor, weighing 9 cwt. 19 qrs. 4 lbs. broke in succession the following anchors on the old construction, without receiving the least injury; viz. one of 10 cwt. 3 qrs. 4 lbs. for hempen cables; one of

10 cwt. 2 qrs. 12 lbs. and one of 12 cwt. 4 lbs. for chain cables. In place of the usual ring, there is a bolt and shackle *c*, *Figs.* 1 and 4, when the anchor is to be used with chain cables; but when hempen cables are to be used, a ring *d* is connected to the shackle *c* by an additional shackle and bolt *e*. The anchor-stock *f* may be formed either of a single piece, or of two pieces hooped together, and is secured in its place as follows: The bolt and shackle *c* being withdrawn, the small end of the shank is passed through the eye of the stock *f*, (which is defended by an iron plate *g* on each side); the collar *h* is then put over, and the stock is keyed up against the hoop *i* by the forelock key *k* passing through a hole in the shank; by this means the anchor may be stocked or unstocked without the assistance of a carpenter, which is a great recommendation, as a considerable length of time is required to stock an anchor in the common way. These anchors have been pretty extensively adopted, and several parties who have made trial of them have given satisfactory certificates of their efficiency. In connexion with improvements on anchors, it may not be altogether out of place to mention some improvements in the method of letting them go.

Two improved methods of letting go anchors are described in the *Transactions of the Society of Arts.* The principle is the same in each, and consists in supporting the end of what is termed the standing part of the cat-head stopper and shank-painter, by bolts turning upon pivots, and retained in a proper position by a catch, which being withdrawn, the bolt turns upon its pivot, and the stopper slips off, by which means all risk of jamming the turns of the stopper (as in the common method of letting go the running end) is avoided; the danger to the men on the forecastle is done away, and the anchor can be let go at a moment's warning.

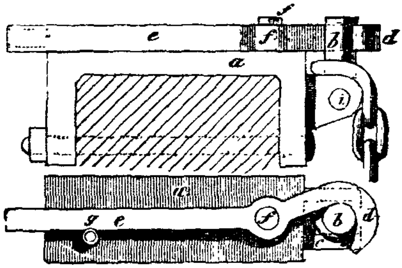
The arrangements in each of these inventions being the same, whether applied to cat-head stoppers or shank-painters, we shall therefore show one invention as applied to cat-head stoppers, and the other to shank-painters. The subjoined cuts show Capt. Burton's method of letting go a cat-head stopper *a*



is the cat-head; *b c* a bolt, turning upon a pivot *d;* the end *c* forms an oblique plane, and is held down by the clamp *e* turning upon a pivot *f*, the clamp being secured by a hasp *g* and pin *h*. *i* is the standing end of the stopper, having an eye formed in it, which passes over the end *b* of the bolt *b c;* the other end of the stopper passes through the ring of the anchor, and over the thumb-cleat *k*, and is made fast round the timber-head *l*. When it is required to let go the anchor, a hand-spike is inserted between the thumb-cleat *k*, so as to nip the clamp *e*, and the hasp *g* is cast off; then upon withdrawing the hand-spike, the bolt being no longer held by the clamp *e*, turns upon its pivot *d*, by the weight of the anchor on the stopper, and the eye of the stopper slips off the end of the bolt.

The following cut represents Mr. Spence's invention for letting go a shank painter. *Fig.* 1 is an elevation, and *Fig.* 2 the plan. *a* is a cast-iron carriage,

Fig. 1. Fig. 2.

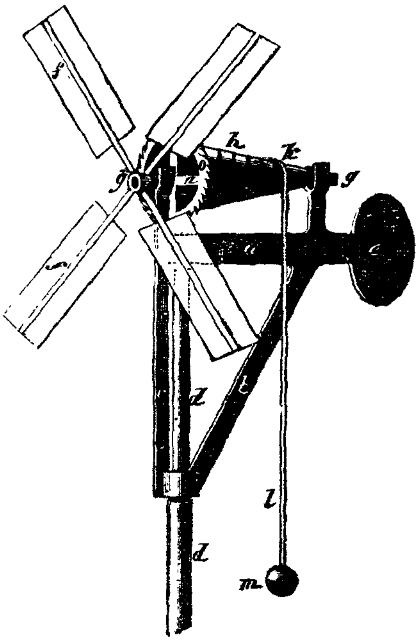


bolted through the ship's side, and supporting the hook *b* by a pin or pivot at *c*; *d e* a lever turning upon a centre *f*, the end *d* being formed into a hook, which clasps the upper end of the bolt *b*, the lever being retained in the position shewn in the plan, by a pin *g*; *h* is part of a chain forming the standing part of the shank-painter, and supported by the bolt *b*. To the other end of the chain is spliced the running part of the shank-painter, which passes round the shank of the anchor, and is made fast to a timber-head. When it is required to let go the shank-painter, an iron bar is inserted into the end *e* of the lever *d e*, which is made hollow for the purpose, and the pin *g* being withdrawn, the lever is turned round its centre until the bolt is released from the hook *d*, when it falls, and the chain end of the shank-painter slips off.

ANCHUSA. Yellow anchusa, or blue-flowered bugloss. The juice of its corolla or flower, gives out, on the addition of acids, a beautiful green. An infusion of these flowers is given in inflammatory bilious diseases.

ANIL. The plant from which indigo is prepared. See Indigo.

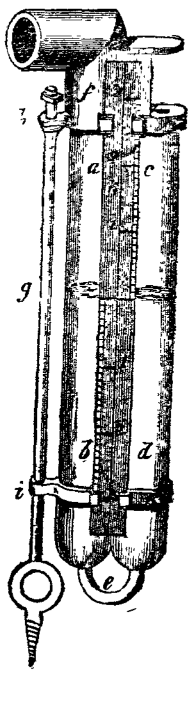
ANIME is a resinous substance, commercially, but improperly, called *gum anime*; for, like resins, it is totally soluble in alcohol, and also in oil, while water will not take up more than a sixteenth part by weight. There are two kinds, distinguished by the terms oriental and occidental. The former is dry, and of colours varying from green to red and brown. The latter is of a yellowish white, transparent, and somewhat unctuous, tears, and partly in large masses, brittle, of a light pleasant taste, easily melting in the fire, and burning with an agreeable smell. The spirit of the alcoholic solution, when drawn off by distillation, preserves the taste and flavour of the anime; the distilled water exhibits on its surface a portion of essential oil. This resin is much used in perfumery. It has also been imagined to be of important service in plasters, employed to relieve nervous affections of the head and other parts.



ANEMOMETER. An instrument for measuring the strength or velocity of the wind. Among various machines which have been constructed for this purpose, the following one has been found to answer very well. It consists of an open frame *a b c*, supported by a shaft *d*, upon which it turns by the action of the wind upon the vane *e*. *f f* are sails, fixed to one end of the axis *g*, and disposed to be influenced by the wind in the usual manner. Upon this axis is also fixed a conical barrel of wood *h k*, on the smaller end of which *k* is attached a line *l*, with a weight

appended to it. The wind acting upon the sails, causes the barrel to revolve, and the line to be wound up on its superfices. To prevent any retrograde motion, a ratchet wheel *o* is fixed to the base or larger end of the cone, having a clicker falling into the notches as it revolves. It is evident that the power of the weight will continually increase as the line advances towards the base of the cone, as the weight acts at a greater distance from the axis or fulcrum; consequently, the variable force of the wind may be readily ascertained by fixing the line at the smallest end, and marking the barrel with spiral lines, as taken up by the coiling of the rope round its superficies, placing also between the lines numerals to denote the force of the wind, which may be calculated with tolerable precision upon the principles of the lever. The diameter of the cone should be such in comparison with its smallest end, that the force of the strongest wind should have scarcely sufficient force to bring the line on to the base of the cone.

Although the instrument above described gives an accurate idea of the comparative force of the wind at different times, it does not point out the actual force exerted on a given surface, nor can observations made with one instrument in a particular place, be compared with observations made by another instrument elsewhere. It is also cumbersome, and not portable. In the *Philosophical Transactions* for 1775, Dr. Lind gives a description of a very ingenious portable wind gauge, which indicates the actual force of the wind by the column of water which it will support. This instrument consists of two glass tubes *a b c d*, which should not be less than 8 or 9 inches long, the bore of each being about $\frac{4}{10}$ of an inch diameter, and connected together by a small bent glass tube *e* of about only $\frac{1}{9}$ of an inch bore, to check the undulations of the water caused by a sudden gust of wind. On the upper end of the tube *a b* is fitted a thin metal tube *f* which is bent at right angles, and has its mouth open to receive the wind blowing into it horizontally. The two branches of the tube are at liberty to turn round a steel spindle *g*, which passes through two slips of brass *h i* near the top and bottom of the instrument. The spindle is fixed into a block of wood by a screw in its bottom. When the instrument is used, a quantity of water is poured in until the tubes are about half full, and the instrument being then held perpendicularly, with its mouth exposed to the wind, the water will be depressed in the tube *a b*, and proportionably elevated in the tube *c d*; and the distance between the surfaces in the two tubes measured by a sliding scale of inches, and parts *k* attached to the instrument, will be the height of a column of water which the wind is capable of sustaining at that time; and as a cubic foot of water weighs 1000 oz. or $62\frac{1}{2}$ lbs. nearly, the twelfth part of which is $5\frac{5}{24}$ lbs., therefore every inch the surface of the water is raised, the force of the wind will be equal to so many times $5\frac{5}{24}$ lbs. on the square foot. This instrument shows the *force*, but not the *velocity*, of the wind; but as the force is as the square of the velocity, if the velocity due to a given force be ascertained, a table of the velocities corresponding to each inch the water is elevated, may be calculated and engraved upon the scale of equal parts. The following table, showing the corresponding height of water, velocity of the wind, and the force exerted upon a square foot of surface, has been calculated from some experiments made by Dr. Hutton.



Height of Water. Inches.	Force of Wind. lbs.	Velocity per Hour. Miles
$\frac{1}{4}$	1.3	18
$\frac{1}{2}$	2.6	25.6
1	5.2	36
2	10.4	50
3	15.6	62
4	20.8	76
5	26.	80.4
6	31.25	88
7	36.5	95.2
8	41.7	101.6
9	46 9	108
10	52.1	113.6
11	57.3	119.2
12	62.5	124

ANISEED. A medicinal seed produced from a species of pimpinella which grows naturally in Egypt, Syria, and other eastern countries. In France it is cultivated for culinary and medicinal uses. Aniseeds are roundish and striated, flatted on one side, and pointed at one end; of a pale colour, inclining to green. They have an aromatic smell, and a pleasant warm taste. Their virtue is entirely given out to alcohol, when it forms, combined with syrup, the well-known cordial of this name.

ANNEALING. The process by which metallic, and other mineral productions, are converted from a brittle to a comparatively tough quality, presumed to be caused by a new arrangement of their constituent particles. In a considerable number of bodies that will bear ignition, it is found that sudden cooling renders them hard and brittle, while, on the contrary, if they are allowed to cool very gradually, they become softened or annealed. We have, however, noticed several alloys of copper (brass in particular) in which sudden cooling has the reverse effect, that of annealing it. The process of annealing requires some address and experience to perform it in the best manner; and varies in the degree of heat applied, as well as in the period of cooling, according to the nature of the metal or other substance operated upon. In the annealing of steel and iron, the metal is heated to a low redness, and suffered to be gradually reduced in its temperature, covered up, on a hearth. Ovens are constructed for this purpose, wherein the pieces of metal, according to their massiveness, and the quality it is desired they should possess, are placed and retained at a low heat for days, and sometimes weeks together. The annealing of glass is performed precisely in the same manner.

ANNOTTA. The pellicles of the seeds of a liliaceous shrub. The annotta commonly met with among us, is moderately hard, of a brown colour on the outside, and a dull red within. It is used for giving an orange cast to the simple yellows; as an ingredient in varnishes; and besides its use in dyeing, is employed for colouring cheese.

ANTHRACITE. A species of coal called by a variety of names, of which the most common are, stone coal, blind coal, glance coal, Kilkenny coal. There are several varieties, and they possess generally the property of burning without flame or smoke. See Coal, Furnace, and Stove.

ANTI-ATTRITION. A patent for a composition under this name was taken out in this country some years back: it was introduced as a substitute for oil or grease, in lubricating the axle-trees of carriages, and is, of course, equally applicable to the rubbing parts of other machinery. Its composition is simply a mixture of hog's lard with "black lead" (plumbago), in the proportion of four parts of the former to one of the latter. It appears from a Munich journal, that the manufacture of this article in Germany is conducted with more exactness; ten and a half parts are there melted over a moderate fire, when two parts of finely powdered and sifted plumbago are to be added by degrees, and be well stirred with a wooden spatula, until the incorporation of the two sub-

stances is uniform and complete; the mixture is then to be taken from the fire, and the stirring continued until it is quite cold, to prevent the subsidence of the plumbago. When this composition was applied by means of a brush in the cold state to pivots and toothed wheels, the expense was, in consequence, found to be reduced from six florins twenty-nine kreutzers, to one florin thirty kreutzers.

ANTIMONY. A brilliant white metal of a laminated or striated texture. It is very brittle, and cannot be rolled into sheets, or drawn into wire. The spec. grav. of the metal, is 6.712; it melts at 810°, and crystallizes in pyramids when cooling. At an intense heat it is volatilized. The ores of antimony are chiefly found in the north of Europe. There are several varieties, but the sulphuric or grey antimony is the most abundant, and yields the metal of commerce. It is reduced to powder, and heated in a reverberatory furnace; the melted sulphuret then flows from the infusible stony or earthy matter, and is then smelted and purified. The metal is used in the manufacture of printers' types, music plates, specula for telescopes, and is a component of several useful alloys. See ALLOY. A difference of opinion exists among chemists respecting the number of oxides of antimony, some being of opinion that there are only two; others, among whom is Berzelius, that there are four. We shall only describe here the two which appear indisputable. To obtain the protoxide, dissolve the metal in muriatic acid, and pour it into a large quantity of distilled water; this separates the protoxide as a white precipitate, which must be washed with a weak solution of carbonate of potash, to remove any muriatic acid it may contain. This is the basis of all the useful antimonial medicines. The peroxide may be obtained by digesting antimony in nitric acid, and drying the white powder which results at a moderate heat. Antimony is soluble in most of the acids, and combines also with chlorine, iodine, phosphorus, and sulphur. If filings of the metal are thrown into a vessel containing chlorine gas, they burn vividly. Basil Valentine first introduced this substance into medicine, and is said to have performed many extraordinary cures by it. Its virtues he discovered accidentally. Having thrown a preparation of it into a hog-trough, the hogs were violently purged by it, but afterwards fattened with surprising rapidity. Seeing this effect, it is said he administered it to his brother monks in such quantities that they all died: the medicine was therefore called anti-moine, or anti-monk. By more cautious and skilful use, he obtained for it a great reputation; but in 1566 its employment in medicine was prohibited in Paris by an edict of the parliament. The sulphuret of antimony was employed in very early times by the eastern females, and even occasionally by men, for the purpose of staining the eye-brow and lashes, and even the lids, to make the eye appear larger. This practice is frequently alluded to in the Scriptures. There are many valuable medical preparations of antimony, the most important of which, perhaps, is the medicine called Dr. James's Powder. This is a compound of protoxide of antimony, and phosphate of lime. The precise mode of preparing it is not known to chemists; the pulvis antimonialis of the shops is, in composition, similar to James's powder, but its effects as a medicine are not so certain nor so powerful. Tartar emetic, or tartarized antimony, is a triple salt, composed of tartaric acid, potash, and antimony. Powder of algaroth is the protoxide of antimony precipitated from the muriate by water. Kerme's mineral is a hydro-sulphuret of the metal. Antimony is much valued as a medicine for cattle.

ANVIL. A large solid mass of iron, of indispensable use in smiths', as well as many other workshops, for hammering or forging work upon. They are made of various sizes, from the weight of a few pounds (or even ounces,) up to many hundred weights each; and they are much varied in form, to adapt them to the nature of the work they are designed for. Their general figure is that of a parallelopipedon, with its lowest side spread out at the corners to steady its seat upon a wooden block upon which they are mounted, and confined by large nails or staples. The face, or upper side, of most anvils are perfectly flat and smooth, and are made of steel, and so hard as to resist the file. At one end of the anvil is a "beak-iron," which is a projecting piece, tapering to

a point, for the purpose of turning or bending the metal under operation; and there are also one or more holes made on the face, for the convenience of punching holes in the work, or for the reception of fixed cold chisels, stakes, or indeed any kind of tool that it may be desirable to adapt to it.

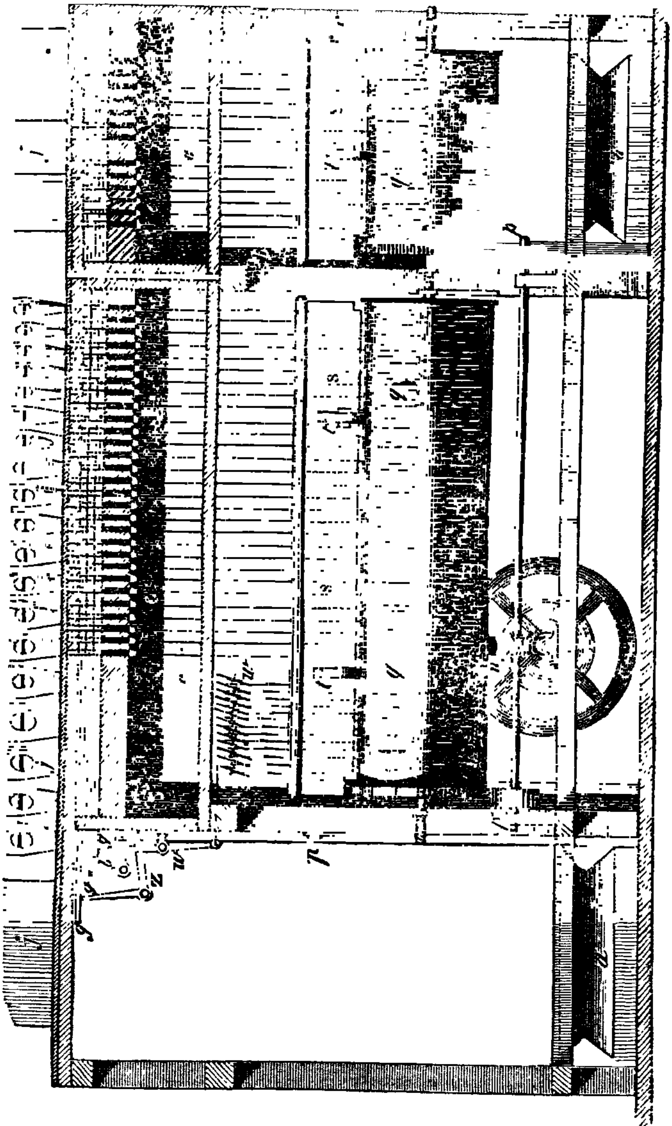
APIARIES. A place where bees are kept; the term is considered to apply to a collection of hives, and not to a single one. See BEEHIVE.

APOLLONICON. A musical machine, on the principle of the organ, which, by peculiar modification of the pipes, produces an excellent imitation of the tones of all the most admired wind instruments; the combined effect of the whole being similar to that of a numerous and well-chosen orchestra. This magnificent contrivance, unrivalled in this or any other country, is the invention of Messrs. Flight and Robson, who spent five years in its completion; and as a popular description of it has not yet appeared, and cannot fail to be acceptable to the amateurs both of musical and mechanical science, we propose to give such an account of the instrument as may serve to convey a general idea of its construction. In the apollonicon, as in the organ, the sound is produced by a current of air, urged by bellows, through several series of vertical pipes. In the apollonicon there are two pair of bellows, placed below the floor of the apartment in which the instrument stands; the wind from which passes through a reservoir and a tube, called a wind trunk, into an air-tight compartment, called a wind chest. The pipes which, by various modifications of their construction, produce the sounds of the different instruments, are ranged in rows one behind the other, parallel to the front of the machine, in the order of the gamut, each note and half note having its separate pipe, and each parallel row representing a different instrument; the pipes producing the same note in every instrument lying in a straight line from front to back of the instrument, or parallel to its sides. Thus the pipes producing the note *A* on the flute, clarionet, bassoon, &c., all lie in a line parallel to the sides of the instrument. From the upper part of the wind chest proceeds a horizontal platform, termed the bottom board, having a series of channels cut in its upper surface, corresponding to each note of the different scales, and extending longitudinally from front to rear of the machine. Above the bottom board, and at right angles to the channels, are a series of grooves, corresponding to the transverse ranges of pipes, or the number of the different instruments in each groove, are three slides, placed one over the other, and through all three are cut narrow passages, opening into each of the wind channels in the bottom board. Over the slides is placed the top board, into which the pipes are inserted, communicating with the wind channels through the apertures in the slides. The use of these slides is to cut off occasionally the communication of any particular instrument with the wind chest, so as to cause that instrument to cease playing, which is effected as follows:—the space between each aperture in the slides is somewhat greater than the width of the wind channels, so as to cover the channels completely, and thereby cutting off the communication with the instrument to which the slide belongs. Only one slide in each set of slides is in operation at one time; the apertures in the other two sets being over the wind channels, and below the apertures of the instruments. One set of slides being used when the instrument is played by the mechanical action of the machine, another set is moved by pedals, and the third set by hand, when it is played by the keys. At that end of each wind groove that opens into the wind chest, are two hanging valves, called pallets, which admit the air into, or exclude it from, the wind grooves; and the art of performing upon the machine consists in the management of the pallets and stops before described; the air or tune being produced by the pallets, and the stops regulating the instruments, upon which the air is played. We shall now proceed to describe the means by which this is effected.—The machine may be played in two ways, either by performers seated at ranges of keys, as in other organs, or by mechanical means: and as this latter method is the distinguishing character of the machine, and has called forth so much ingenuity in its execution, we shall describe it first. The principle is as follows:—to one set of the pallets is attached a series of wires (one to each pallet) passing through holes in a brass plate in the bottom of the wind chest,

which are just sufficiently large to allow the wires to move easily, without allowing the air to escape from the wind chest. These wires (60 in number, being one to each note of the scale of the machine,) are connected to one end of a series of small steel levers, set in a frame below the wind chest, the outer end of the levers resting upon the surface of a cylinder somewhat longer than the key-frame; a number of small pins and bent wires or brackets project a short distance beyond the circumference of the cylinder, ranged in lines across the axis, and by the revolution of the cylinder, one or more of these pins or brackets are brought in contact with the outer end of the keys, which are thus raised, whilst the other end of the keys, and the pallets corresponding, are proportionably depressed; the wind passes from the wind chest into the wind passages. The length of time the pallets continue open is regulated by the length of the brackets; and when, by the revolution of the cylinder, the brackets come clear of the keys, the outer end of the key falls upon the cylinder, the pallet is closed by a spiral spring, and the communication with the wind grooves is cut off. Beyond the keys, and towards the end of the key-frame, is a set of similar keys, moved by brackets on the surface of the cylinder, similar to the former, only projecting somewhat more; these keys (called shifting keys,) by an ingenious arrangement (which we shall afterwards describe at length), give motion to an equal number of levers, each one of which moves in or out one or more of the set of stops which are governed by the cylinder, and thus opens or cuts off the communication of the corresponding instrument or set of pipes. For the sake of simplicity, we describe the brackets as ranged in lines standing right across the axis, which is not quite correct, as, in this case, the same keys would be moved at the corresponding part of each revolution of the cylinder, and consequently only very short pieces could be performed, or the cylinder must be of an inconveniently large diameter. To remedy this, the cylinder is allowed to move endways in its bearings, a space equal to the distance between two keys; on its axis is cut a screw, containing nine threads, and the bevelled edge of a lever, called a knife, taking in one of the threads of the screw, the cylinder would be moved endways, at each revolution, a space equal to the distance between two threads; or one-ninth of the distance between two keys, at each revolution; and the ends of each key would trace a spiral line on the barrel, likewise deviating from a straight line one-ninth of the distance between two keys; thus nine revolutions of the cylinder would be made before the spiral traced by one key could be brought under the next key. Now the brackets and pins being ranged on the cylinder along these spiral lines, it is clear a different key may be moved at each corresponding part of a revolution, for nine revolutions, which renders the barrel equal to one of nine times its diameter, in which the brackets should be placed in right lines surrounding the cylinder; and as the cylinder revolves very slowly, it is sufficient for the performance of most compositions. If it is required to repeat the performance, the key-frame is turned back upon a hinge, which raises the keys clear of the pins, and the knife being lifted out of the screw cut on the axis, the cylinder is moved endways into its original position, the knife replaced in the screw, and the key-frame again brought down to the cylinder, when the piece may be repeated. Having thus explained the principles of the mechanical action of the machine, we shall proceed to notice some of the details of the arrangement. There are three cylinders, each 2 feet in diameter, and each having a separate wind chest and key frame placed over it, furnishing wind to particular portions of the scale. The main cylinder occupies the centre of the front of the machine; it is 8 feet long, and comprises a range of five octaves: viz. from G G an octave below first G in the bass clef up to G, and eighth above G in the treble clef. In a line with this, and concentric with it, is another cylinder, 3 ft. 9 in. for the bass notes extending from G G G, or an octave below the former, up to gamut G, being two octaves. The third cylinder lies at the back of the machine, parallel to the main cylinder; it is 8 feet long, and comprises two octaves. Below the two front cylinders extends a shaft, or axis, having two pinions, which work in two wheels, one on the end of each cylinder, and a similar shaft lies below the third cylinder, in the rear of the machine; and beneath these shafts, and at right

angles to them, is another shaft, extending from the front to the back of the machine, having on it two endless screws working in worm-wheels on the two shafts; this last shaft receives its motion by a band from the driving-shaft, (which has a fly-wheel, and is turned by manual labour), and causes the cylinders to revolve. The key-frame is made in distinct pieces, to allow for the unequal

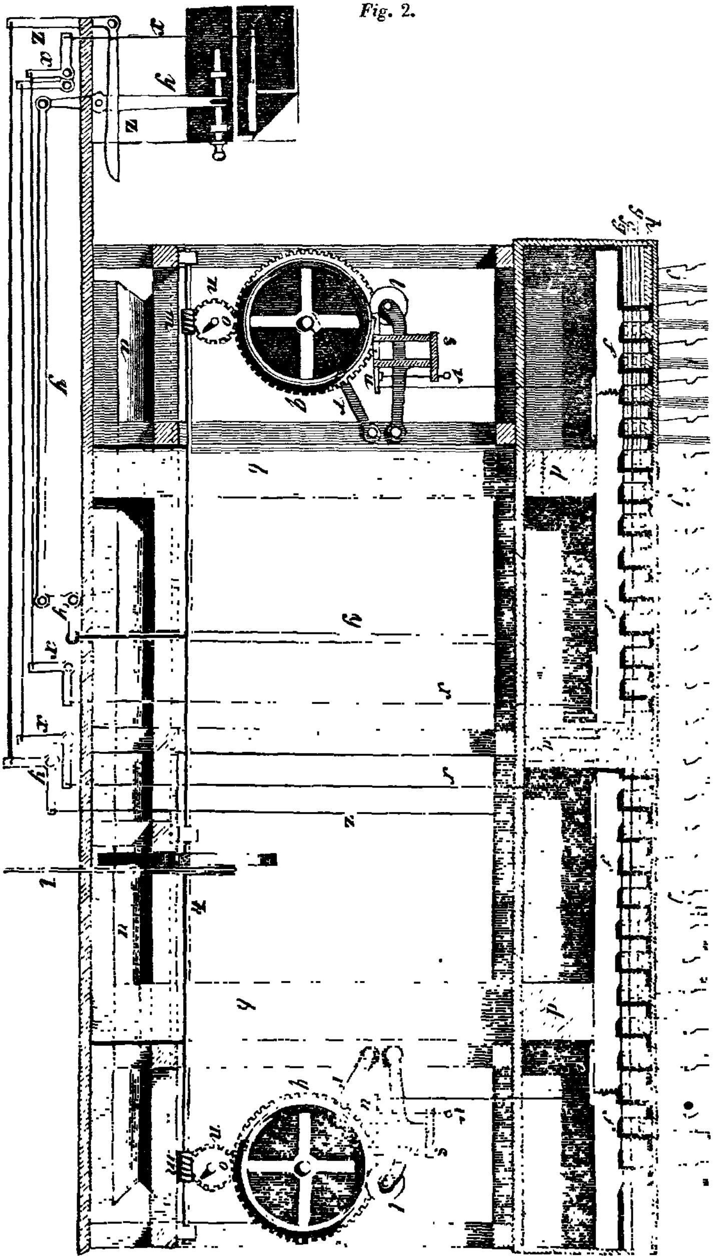
Fig. 1.



contraction of the wood, and any inequalities which may exist in the cylinder; and to take the weight off the key, it is supported on the cylinder by anti-friction rollers. It remains now to explain the connexion of the finger-keys with the pallets. The key-boards are five in number, the central largest comprising a

scale of five octaves, and the smaller ones disposed two on each side of the larger, these containing a scale of three octaves. These keyboards stand in front of the instrument, and detached from it, so that the performers sit with their backs to the instrument, and their faces to the audience. From the

Fig. 2.



fore end of the finger keys descend wires to the fore end of a series of levers below the floor, and to the other end of these levers are attached wires, which pass through holes in the wind chest, and are fastened to their set of pallets, and thus the depression of the finger keys draws down the hinder ends of the lower levers, and opens the pallets. Within reach of the performers at the keys, are a number of levers for moving by hand the draw-stops as are termed the slides which throw off or on any particular instrument; but, in addition to these, are a set of pedals five in number, which move a set of stops, called compound pedal stops. These are the invention of Mr. Robson, and are for the purpose of enabling the performer suddenly to throw on or off a number of instruments by a single movement, and thereby add greatly to the brilliancy of effect. The operation of these stops requiring a figure for its elucidation, will be deferred until afterwards. To enable the reader more fully to comprehend the foregoing description, we have subjoined two engravings, *Fig.* 1 being a section of the machine parallel to the barrels, or to the front; and *Fig.* 2 a section across the barrels, or at right angles to the former. In these figures, we have not strictly adhered to the actual arrangement of the parts which are used in the instrument itself, but have rather endeavoured to give a general idea of the principle of the construction, which is all that our limits will allow. In each figure the same letters denote similar parts. *a a* are the reservoirs immediately over the bellows; *b* the wind trunk; *c* the wind chest; *d d* strengthening bridges; *e e* pallets; *f f f f* wind grooves or channels; *g g g* the stops or slides; *h h* the groove board, into which are inserted the foot of the pipes *j j j*; *k* the driving shaft, turned by a band *l*, from a wheel below the floor; *m m* endless screws working into worm wheels *n n* on the transverse shafts *o o*; *p p* pinions driving the cylinders *q*; *r* the knife or guide; *s* the key-frame; *t t* anti-friction rollers; *u u* the keys; *v v* stops to prevent the keys striking the cylinder; *w w* shifting keys with the connexion to their stops; *x* connexion of the pallets with the finger keys; *y* connexion of draw stops; *z* connexion of compound pedal stops. Having thus explained the general mechanical arrangement of the instrument, we shall proceed to explain more minutely the manner of throwing on or off; the different instruments or ranges of pipes, both by the shifting keys, and by the compound pedal stops. The

Fig. 3.

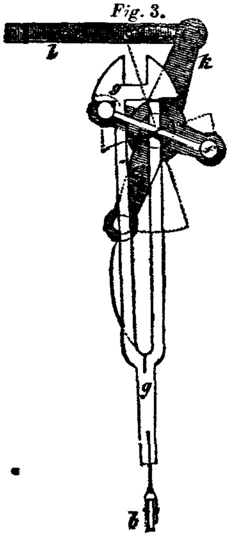
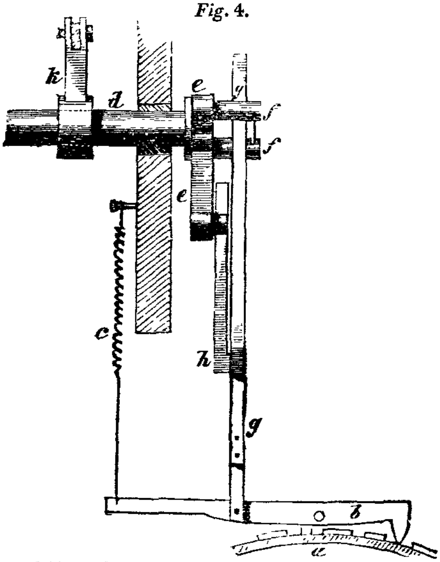


Fig. 4.



above cuts represent one of the shifting keys, *Fig.* 3 being a front view, and *Fig.* 4 a side view. *a* represents a portion of the cylinder; *b* one of the shifting

keys, kept in contact with the barrel by the spring *c*. On the spindle *d* is keyed a T-shaped lever *e*, in the horizontal arms of which are two projecting studs *f f*, with a wire passed through them from one to the other. A piece of brass *g* is attached at its lower end to the key *b*, and the upper end passing between the lever; the wire rests by one of its shoulders on one of the projecting studs; a steel spring blade *h* is inserted at its lower end into a cleft in the piece *g*, and passes through a slit in a stud in the lower end of the lever *e*, and by its tendency to recover a right line in the direction of the arm, it forces the piece *g* out of the perpendicular, so that it shall always rest against one or other of the studs. *k* is an arm upon the spindle *d*, connected by a bar *l* to the lever (not shown) which works the slide or stop. Now when the tooth of the key is raised by one of the studs of the barrel passing under it, the other end of the key is depressed, and drawing down the piece *g*, shifts the lever *e* into the position shown by the dotted lines, and thus reverses the position of the slide. When the stud has passed the key, the spring *c* returns the key to its former position, and the piece *g* in rising is thrown by the spring *h* against the stud in the upper arm of the lever *e*. The compound pedal stops are a most admirable invention of Mr. Robson's, by means of which the performer is enabled to throw off instantaneously a number of instruments, and to bring into play a number of others, as the varying nature of the music may require, with an effect and precision equal to that of the best appointed orchestra. The mechanism is extremely ingenious, as well as beautifully simple. The arrangement will be easily understood by referring to the annexed cuts, which represent one set of pedal levers,

Fig. 5. *Fig.* 6.

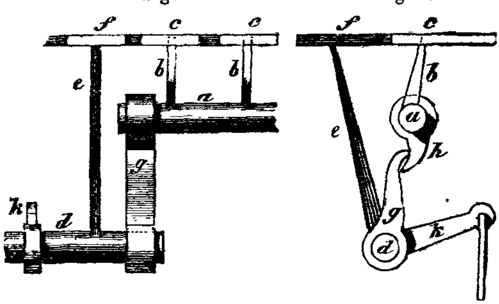


Fig. 5 being a side view, and *Fig.* 6 an end view. On the upper axis *a* is a number of arms *b b* acting upon slits in a corresponding number of slides *c c;* on the lower axis *d* is likewise one or more arms *e* acting on one or more slides *f;* on the axis *d* is a tooth *g* acting upon a similar tooth *h* on the axis *a;* the length of each tooth being proportional to the length of the arms *b* and *d*. *k* is an arm, connected by wires and bell-cranks to the pedal beneath the key-boards. Now upon depressing this arm, it will be seen that the arms *b b* and *d d* will move over equal spaces in opposite directions; one set of slides will therefore open the communication between the wind grooves and the instruments to which they belong, and the other set will close the passages to which they belong, and thus throw out of play the corresponding instruments; and there being five of these compound pedal stops, an amazing variety of changes may be obtained by varying the combinations of the slides. The whole number of the keys acted upon by the cylinders is about 250. There are upwards of 1900 pipes, 45 draw-stops, and 2 kettle-drums. To the musical amateur the following list of the stops will doubtless prove interesting.

On the first cylinder,—

1. Open Diapason.	4. Principal.	7. Flute.
2. Ditto ditto.	5. Twelfth.	8. Sesqui Altera.
3. Stop ditto.	6. Fifteenth.	9. Cornet—Trumpet.

On the second cylinder are two octaves of wooden pipes, of large dimensions, termed double diapason pedal pipes: the largest is 24 inches long, and 23

square; this is 8 feet longer than the corresponding pipe in the great organ at Haarlem. The range of the scale is from G G G to G.

On the third cylinder are the following stops,—

Diapason, or Corni Stop.	Trumpet.	Hautboys.
Stop Diapason.	Cremonas.	Piccolais.
Violoncello.	Flutes.	Trumpets.
German Flute.	Vox humana.	Diapason.
Wood Fifteenth.	Octave Flute.	Principal, &c.

The mechanism is enclosed in a case, 20 feet broad by 18 feet deep, and 24 feet high. The front is divided into three compartments by pilasters of Grecian Doric, surmounted by others of the Ionic order. Between the upper pilasters are three paintings; that in the centre representing Apollo, and those on the sides the Muses, Clio and Erato, somewhat larger than life, which do much credit to the artist (Mr. John Wright) by whom they were painted. The mechanical action of the apollonicon was first exhibited to the public in June, 1817, when the overtures to Anacreon and to the Clemenza di Tito were performed by the cylinders in a style that called forth the most marked approbation from large and scientific audiences. From that period to the present time it has maintained its well-deserved popularity, and continues an object of interest alike to the musician and the mechanist, offering to the former some of the grandest combinations of harmony, and to the latter some of the most curious and complicated specimens of his art.

AQUA FORTIS. The old and still popular name for nitric acid. The article sold in the shops under this name is generally prepared by mixing common nitre with an equal weight of sulphate of iron, and half its weight of the same sulphate calcined, and distilling the mixture; or by mixing nitre with twice its weight of dry powdered clay, and distilling in a reverberatory furnace. Two kinds are found in the shops, one called *double aqua fortis*, which is about half the strength of nitric acid; the other simply *aqua fortis*, which is half the strength of the double. See Acid, Nitric.

AQUA REGIS. This having been the first solvent that was discovered for gold, the king of metals, was called by this name, signifying the king's water. The original and proper aqua regis is made by adding four ounces of common salt to an avoirdupois pound of aqua fortis. Homberg says, aqua regis is of proper strength to dissolve gold, when a bottle, holding sixteen ounces of water, holds seventeen ounces of the acid; that is to say, when it is of the specific gravity 1.062.

AQUA TINTA. See Engraving.

AQUA VITÆ. Ardent spirit of the first distillation has been distinguished in commerce by this name. The distillers of malt and molasses spirits call it low wines.

AQUEDUCT. A conduit for water, constructed of different materials, built on uneven ground, for preserving the level of water, and conveying it from one place to another. Aqueducts are distinguished into two classes; the visible, or such as are built on arches across valleys and marshes, and the subterraneous, which are formed by piercing mountains, and conveying the water below the surface of the earth. These constructions were formed of brick, stone, &c., and covered either with vaulted roofs, or flat stones, which served to shelter the water from the influence of the sun and rain. They were, in some cases, paved, and, in others, the water was conveyed through a natural channel formed in the clay. It was also frequently conducted by leaden pipes into reservoirs of the same metal, or into troughs of hewn stone. Some aqueducts are supported on single, others on double, or triple, ranges of arches. Of the latter kind is the Pont du Gard in Languedoc, supposed to have been built by the Romans, to convey water to the city of Nismes; that at Constantinople, and that which, according to Procopius, was constructed by Cosroes, king of Persia, near Petra, in Mingrelia, and which had three conduits in the same direction, each elevated above the other. The Romans had many magnificent aqueducts, surprising on account of their magnitude and number, as well as their construction and length; some bringing water through a distance

of from thirty to one hundred miles, either upon a series of arches, or by means of excavations through mountains and rocks. This is well expressed by Pliny in the following language: "If we consider the incredible quantity of water brought to Rome for the uses of the public, for fountains, baths, fishponds, private houses, gardens, and country seats; if we represent to ourselves the arches constructed at a great expense, and carried on through a long distance; mountains levelled, rocks cut through, and valleys filled up; it must be acknowledged that there is nothing in the whole world more wonderful." The waters of the Tiber, with the wells and fountains in the neighbourhood, had supplied the wants of the Romans for four centuries and a half, when Appius Claudius, the censor, advised and constructed the first aqueduct. His example was speedily followed, and the courses of rivers were thus changed and diverted towards Rome, to supply the daily increasing wants and luxuries of the Roman people. At certain distances, vents were provided, in order that the water, which was accidentally obstructed in its progress, might be discharged till its ordinary passage was cleared; and, in the canal of the aqueduct itself, there were cavities into which the water was precipitated, and where it might remain till its mud was deposited, and the water become clear. A considerable variety was observable in the construction of aqueducts. The aqueduct of the Aqua Marcia had an arch of sixteen feet diameter. The whole was composed of three different kinds of stone; one of them reddish, another brown, and a third of an earth colour. The entire edifice is 70 Roman feet in height. Above them appeared two canals, the highest of which was fed by the waters of the Tiverone, and the lower, by what was called the Claudian River. Near this aqueduct, Montfaucon gives the plan of another with three canals; the highest supplied by the Aqua Julia, that in the middle from Tepula, and the lowest from the Aqua Martia. The arch of the aqueduct of the Aqua Claudia was of hewn stone, very beautiful; that of the aqueduct of the Aqua Meronia was of brick. Each of these was 72 feet high. The Aqua Appia deserves notice for the singularity of its construction, it not being plain or gradual in its descent, but much narrower at the lower than at the upper end. The consul Frontinus, who superintended the aqueducts under the emperor Nerva, mentions nine, each of which had 13,594 pipes of an inch diameter; and it is stated by Vigerus, that, in the space of twenty-four hours, Rome received, by means of these erections, 500,000 hogsheads of water. In modern times, the aqueduct of Legovia is considered the most magnificent. There still remain 159 arcades, wholly consisting of stones, enormously large, and joined without mortar. These arcades, with what remain of the edifice, are 102 feet high; there are two ranges of arcades, one above the other. In 1684, Louis XIV. caused an aqueduct to be commenced near Maintenon, for carrying water from the river Eure to Versailles; but the work was abandoned in 1688. This would, probably, have been the largest aqueduct in the world, the whole length being 60,000 toises; the bridge 2,070 fathoms in length, 220 feet in height, and consisting of 632 arches. The principal ancient aqueducts now in being, are those of the Aqua Virginia, Aqua Felice, and Aqua Paulina. The quantity of water supplied by the whole of the aqueducts in ancient Rome, is calculated to have amounted to the enormous quantity of 50,000,000 cubic feet daily; which, reckoning the population of Rome at 1,000,000, allows 50 cubic feet for the daily consumption of each individual. The supply of water to London in 1790, amounted to 2,626,560 cubic feet daily; and even at the present day, it does not exceed 4,000,000 feet. This quantity, although found abundantly sufficient for our use, is little more than a twelfth part of the quantity consumed by the Romans. The daily supply of water to Paris is still less, being about 293,000 feet, or half a cubic foot for the daily use of each inhabitant. The Greeks of the lower empire simplified the general mode of conducting water, and reduced the expense to a fifth part, chiefly by the introduction of the Soulerazi, or water-balance, a sort of hydraulic obelisk. The water runs down a gentle slope in covered drains, till it reaches an obelisk constructed of masonry, and rising up one side in a narrow channel, discharges itself into a bason at the top, from which again, at a level 8 inches lower, it descends by a similar channel on the other side.

The charge of the water-works at Constantinople is entrusted to a body of 300 Turks, and certain Albanese Greeks, who make it almost an hereditary profession. The supply for each person is stated to be about two-thirds of a cubic foot, or 42 pounds daily. There are two ancient cisterns still extant in Constantinople: the subterranean cistern, built of hand-brick, vaulted, and resting on marble columns; and the cistern of 101 columns, anciently called Philoxene. The latter consists of three rows of columns, one above another, and is capable of holding five days' supply of water for the whole inhabitants of this spacious city. Among the most modern must be noticed the aqueduct of Chirk, in Denbighshire, constructed by Mr. Telford for the purpose of carrying on the navigation of the Ellesmere canal. It consists of 10 arches, supported by pyramidal stone piers, and extends to about 600 feet in length. The summit of the central arch is 65 feet above the level of the water.

ARABIC GUM. This gum, which flows naturally from the acacia, in Egypt, Arabia, and elsewhere, forms a clear transparent mucilage with water: it is insoluble in alcohol and ether. It is used in medicine, and is considered as a specific against the strangury occasioned by blisters; it constitutes, under particular forms, a nutritious food, and it is an important article in various manufactures.

ARCH, or Arc. In geometry, a part of a curve line, as of a circle or an ellipse, &c. Arch, in architecture, an aperture, the upper portion of which is bounded by curve lines, as we see in porches, bridges, &c.; they are of various forms, and are designated by various names, according to their figure, as circular, elliptical, cycloidal, &c. Arch of equilibrium, in the theory of bridges, is that arch which is in equilibrio in all its parts, and therefore equally strong throughout, having no tendency to break in one part more than another. The arch of equilibration is not of any determinate curve, but varies according to the figure of the extrados; every different extrados requiring a particular intrados, so that the thickness in every part may be proportional to the pressure. The subject has occupied the attention of several eminent mathematicians, and has been fully treated by Dr Hutton, in his "Principles of Bridges," and in some of his tracts; where the proper intrados is investigated for every particular form of extrados; and it shews, that in semicircular and semielliptical arches, and, in fact, in all arches springing perpendicularly from a horizontal line, the line of their extrados becomes assymptotical as it approaches a perpendicular passing through the points from which they spring, and that such arches require to be loaded infinitely over the haunches. But the researches of mathematicians upon this subject, although they are not without utility, have not been of any great service to the practical builder, who, guided by a set of maxims which are the fruits of observation and experience, constructs arches of immense span, differing widely from the form assigned by theory, which are, nevertheless, stable and durable. This arises, perhaps, not from the theory being false, but from its being imperfect; mathematicians calculating the effects of gravitation only, without allowing for those of cohesion, friction, and some other forces, which undoubtedly operate in an arch, although it is difficult to estimate their several quantities. Hence in practice it is found sufficient if the arch of equilibrium be comprised within the boundaries of the voussoir, or stones, forming the arch, without its being necessary for either the intrados or extrados to conform exactly to that curve. For good practical views on this subject, we refer our readers to *Gwilt's Equilibrium of Arches*, and to the article "Bridges," in the *Edinburgh Encyclopædia*.

ARCHIL. A whitish lichen, growing upon rocks in the Canary and Cape Verd Islands, which yields a rich purple tincture, fugitive, indeed, but extremely beautiful. This weed is imported to us as it is gathered: those who prepare it for the use of the dyer grind it betwixt stones, so as to thoroughly bruise, but not to reduce it into powder, and then moisten it occasionally with urine, or mix quick lime with the urine: in a few days it acquires a purplish red, and at length a blue colour; in the first state it is called archil, in the latter, lacmus, or litmus. The dyers rarely employ this drug by itself, on account of its dearness, and the perishableness of its beauty. The chief use they make of

it is for giving a bloom to other colours, as pinks, &c. This is effected by passing the dyed cloth or silk through hot water, slightly impregnated with the archil. The bloom thus communicated, soon decays upon exposure to the air. By the addition of a little solution of tin, this drug gives a durable dye; its colour is at the same time changed toward a scarlet, and that is the more permanent, in proportion as it recedes the more from its natural colour. Prepared archil very readily gives out its colour to water, to volatile spirits, and to alcohol; it is the substance principally made use of for colouring the spirits of thermometers. As exposure to the air destroys its colour upon cloth, the exclusion of the air produces a like effect in those hermetically sealed tubes,—the spirits of large thermometers becoming in a few years colourless. The Abbé Nollet observes (in the French Memoirs for 1742), that the colourless spirit, upon breaking the tube, soon resumes its colour, and this for a number of times successively; that a watery tincture of archil, included in the tube of thermometers, lost its colour in three days; and that in an open deep vessei it became colourless at the bottom, while the upper part retained its colour. A solution of archil in water, applied on cold marble, stains it of a beautiful violet or purplish blue colour, far more durable than the colour which it communicates to other bodies. There is a large establishment at Glasgow for an article of this kind, which is much esteemed; it is sold by the name of cudbear. Silks thus dyed with it are said to be very permanent, of various shades, from pink and crimson to a bright mazarine blue.

ARGAL. Crude tartar, in the state in which it is taken from the inside of wine vessels, is known in the shops by this name.

ARGAND BURNERS. See Lamps.

AROMATIC VINEGAR. An acetic solution of camphor, oil of cloves, oil of lavender, and oil of rosemary; a sufficient quantity of each to make it pleasant.

ARRACH. A spirituous liquor, imported from the East Indies; it is chiefly manufactured at Batavia and at Goa, upon the Malabar coast.

ARROWROOT. The pure starch of a bulbous-rooted plant, growing in the West Indies, and other warm climates. The starch of the potatoe has precisely the same properties, and, from the superior cheapness of the latter in this country, it forms a common substitute for the foreign production, which is difficult to obtain in the retail shops unadulterated. Under the article Potatoe will be found a full description of the mechanical process employed in extracting the starch from that root.

ARTESIAN WELLS. A name given by the French, and extensively adopted here, to artificial fountains, made by boring the earth, and permitting the confined water to rise. See Boring the Earth.

ARCOGRAPH. An instrument for drawing a circular arc without a central point. There are various ways of performing this, but the following is the most simple, and is often practised by bricklayers and masons. Two nails are driven into the face of the wall upon which the curve is to be struck, the nails being at each extremity of the curve; two laths or straight rods are then nailed together at such an angle as that the apex shall touch the crown of the arch when the two sides are in contact with the nails at the extremities of it; then if the apex of the laths be gradually moved round from one nail to the other, the laths being kept continually in contact with the nails, a tracer placed at the apex will describe the required arch. An instrument of this kind, invented by Mr. Rotch, and rewarded by the Society of Arts, will be found very serviceable for drawing upon paper arcs of very large circles, whose centres lie beyond the limits of the drawing board. It consists of two straight rulers, connected by a joint similar to that of a sector, in the centre of which joint is a socket to carry the tracer. The two limbs are connected to two graduated arcs, sliding upon each other, by means of which the limbs may be set to any angle so as to describe an arc containing any required number of degrees.

ARSENIC. A brittle metal of a bluish white colour, possessing very little lustre. By exposure to the atmosphere it becomes nearly black, and slightly pulverulent. It is very fusible, and is frequently employed to assist the fusion

of other metals. At 356° Fahr. it is volatilized in white fumes, which constitute the arsenious acid, or white arsenic. It is from this substance that the metal of commerce is obtained, and is imported in large quantities from Saxony, the cobalt works of which supply Europe with arsenic. The ores of cobalt contain, with many other impurities, much arsenic. This is dissipated by torrefying them when reduced to powder in a furnace with a long horizontal flue. The arsenious acid becomes condensed in this, and is removed by condemned criminals, the employment being very dangerous, and even fatal to life, on account of the impossibility of preventing particles of this powerful poison from entering the mouth or nostrils. When first volatilized, it is contaminated with sulphur, &c., from which it is separated by mixing with impure potash, and subliming again in close vessels. It then constitutes the white arsenic of the shops. The metal is obtained from this by incorporating it with carbonaceous matter, and heating in a vessel provided with a receiver, to condense the arsenic which rises in vapour. The ores of arsenic are numerous and abundant, and it is a component of an endless variety of minerals. The process of roasting the ores of copper, iron, &c. is unhealthy, chiefly on account of the quantity of arsenic liberated. The minerals called realgar and orpiment (sulphurets of antimony) possess much beauty. Arsenic combines with oxygen in two proportions, the first of which, the arsenious acid consists of arsenic 76 + oxygen 24. The second arsenic, acid of arsenic, 76 + oxygen 40. Both these compounds possess the characteristics of acid bodies; they redden vegetable blues, and combine with many salifiable bases, forming neutral salts. The first of these deserves particular attention, as it is the fatal poison so frequently employed in the destruction of human life by the suicide or the assassin. It is nearly insoluble in cold water, and is, therefore, generally taken in the state of turbid mixture. It adheres with singular obstinacy to the coats of the stomach and intestines, and produces speedy corrosion and inflammation. The symptoms of the poison are generally manifested within a quarter of an hour after it has been swallowed: these are sickness, pain at the stomach, thirst, burning heat in the mouth and fauces, faintings, cold sweats, debility, and at last cramp, and contractions of the limbs. Most, and frequently all, of these symptoms are displayed by the sufferer before death. The only medicines likely to be effectual, are sulphuretted hydrogen water, and copious draughts of bland mucilaginous liquids. Carbonate of magnesia and opium have been on more than one occasion found highly beneficial. In cases of suspected poisoning by this mineral, the contents of the stomach, or the ejected matter, should be carefully saved and digested in distilled water. This must be filtered through porous paper, and, if highly coloured with beer, coffee, or other description of food, a small quantity of newly prepared pure animal charcoal, in powder, must be mixed with it until the colouring matter is destroyed. A second filtration produces a limpid and transparent fluid, susceptible to the action of tests, which must now be applied. To one portion in a test-tube, add a small quantity of transparent lime-water; in a short time, if arsenic is present, the fluids will become turbid and opaque. To another portion, add a few drops of liquid ammonia, and a solution of sulphate of copper; this will produce a bright green precipitate, which is the pigment called Scheele's green. Pass a current of sulphuretted hydrogen gas through another portion, which will convert the arsenic into a sulphuret of a lemon yellow colour. To another portion add a few drops of ammoniated nitrate of silver, which will throw down a golden yellow precipitate, the arsenite of silver. If all these tests produce the effects here described, the corroboration will leave no room to doubt that aresenic was present; but it is advisable, and especially where human life depends on the testimony, to place the matter beyond the possibility of doubt, by reducing the arsenic to the metallic state. This is effected by taking any of the before-named precipitates, and, when carefully dried, mixing it with about an equal quantity of black flux (finely divided charcoal and potash). A few grains of this must be carefully placed at the bottom of a test-tube, so that none shall adhere to the side. The flame of a spirit lamp must now be directed by a blow-pipe against the matter in the tube, and, in a short time, the arsenic will be sublimed, and coat the interior of the glass with the reduced metal of a

shining grey colour; or any of the precipitates may, when dry, be placed on a piece of ignited charcoal, when the arsenic will be volatilized, forming a dense white cloud, and emitting a powerful odour, like that of garlic, which is peculiar to this metal. Arsenic is a metal easily combustible, and, in some cases, burns with singular intensity. If a small quantity is mixed in a mortar with chlorate of potash, a violent explosion takes place. When thrown into chlorine gas, it takes fire spontaneously if finely divided. The spec. grav. of arsenic is 5.763. A sulphuret of arsenic, called orpiment, is extensively used in dyeing. It is prepared by digesting arsenious acid in muriatic acid, and precipitating by sulphuret of ammonia. It is of a bright yellow colour, and produces a permanent dye. Arsenic is used for various purposes in the arts (see ALLOY); it promotes the fusion of other metals, and occasions many that are very refractory to melt at low temperatures. It is employed in the manufacture of lead shot, which it renders more brittle, and more easy to granulate.

ASAFŒTIDA is the concentrated juice of a large umbelliferous plant, which is found in several parts of Asia. The root is of a black colour, and resembles a parsnip; on cutting this transversely, a thick white juice exudes, which, by exposure to the air, becomes of a dark brown colour. The fresh juice has even a more powerful odour than the concrete asafœtida, which resembles that of garlic. The Persians, who export large quantities of it, are compelled to hire vessels on purpose, as its effluvia penetrates every article on board, and spoils many productions. Asafœtida is of a yellowish brown colour, of an acrid taste, and powerful smell. It consists chiefly of gum, resin, and earthy matter. In medicine it is used as a deobstruent, and sometimes as an anthelmintic, and is useful in nervous and hysterical affections.

ASBESTOS (*amianthus*). A fibrous mineral, found in large quantities in Corsica. It is also procured from Savoy, France, Scotland, Sweden, and other places, but is nowhere so abundant as in Corsica. The fibres of asbestos were formerly manufactured into cloth, which was employed in wrapping the dead body intended to be burned; the asbestos being incombustible by fire of the ordinary kind, the ashes of the corpse were thus preserved distinct. Napkins were also made of it, which were cleansed, after use, by burning instead of washing. Wicks of lamps were also made of this material, and are now, in some cases, used with advantage. The art of making the cloth of asbestos seems to have been entirely lost during the middle ages. The Chevalier Aldini has, however, by the agency of steam, succeeded in rendering the tough and brittle fibres sufficiently pliable for weaving into cloth, and exhibited in London gloves, caps, and other parts of dress made of asbestos, which, as being incombustible, and a very bad conductor of heat, he proposed should be worn by firemen.

ASPHALTUM. Called also mineral pitch, Jew's pitch, and bitumen, is a hard black substance, resembling pitch in appearance, but having a higher internal polish. It is found on the shores of the Dead Sea, in China, America, and some parts of Europe. Asphaltum was anciently employed in embalming dead bodies. The Temple of Jerusalem, and the walls of Babylon, are said to have been built of stones cemented together with asphaltum, for which purpose it is well adapted. It is sometimes employed in making black varnish, and is a component of the beautiful black liquid used in printing the numbers on watch and clock faces. The spec. grav. varies from 1.07 to 1.65. It is soluble in oils and ether, if pure Asphaltum was formerly employed in medicine, but it is now seldom administered.

ARTILLERY, in its most extended sense, is applied not only to the guns, projectiles, powder, carriages, &c. used in warfare, but to the men employed in working them. Military engineering, however, not according with the object and scope of this work, the information afforded therein on the subject of artillery is confined to the construction of the most improved FIRE-ARMS, GUNS, PROJECTILES, &c. which see under their separate heads.

ASSAY. The separation of a valuable metal from its alloy or impurities. The art of assaying differs from that of analysis in this respect: by analysis the various component parts of the mineral or alloy are separated, and their

respective quantities estimated; by assay only the valuable metal or metals is sought for. In the assay of gold or silver alloys, for example, the inferior metals are dissipated, and the quantity estimated only by the loss of weight. There are two modes by which the art of assaying is performed, and sometimes one is employed to corroborate the other. The one is called the humid process, by which a solution of the metals is effected by means of acids, after which those sought for are precipitated by proper re-agents; the other is called the dry process, and is performed by the agency of fire. In the mining districts, the comparative value of some ores is roughly estimated by the dry process of assaying. In London, the mode is seldom resorted to, except for the purpose of estimating the quantity of gold or silver in an alloy. The quantity of these metals, or of platinum, in any alloy, may be as correctly estimated by the dry, as by the humid, process; we shall therefore describe the mode of assaying those alloys in this article, and refer the reader to the analysis of ores (see Ore) for the most correct mode of assaying other metallic compounds. An alloy of gold is assayed by detaching from different parts of the article a small portion, by a knife or a file, until the requisite number of grains for the experiment is obtained. These being carefully weighed, are wrapped in a piece of sheet lead, and placed in the bowl of a cupel, and exposed under a muffle to an intense heat. The cupel is a small cubic or circular solid, with a cavity on the upper surface to receive the metal; it is made of a very porous material; the ashes of burnt bones, made into a paste with water and slowly dried, are generally employed for this purpose. When the alloy and lead are exposed to intense heat, as before described, fusion of the whole ensues, but the lead speedily becomes converted into a vitreous oxide or glassy fluid; this powerfully promotes the oxidation and vitrification of any inferior metal contained in the alloy, and when they are thus changed, they percolate through the porous cupel, and leave only a globule of metal not oxidable by heat. This globule, therefore, will be of gold or silver, or a compound of them, these metals, as well as platinum, not being affected by the action of fire and air. To separate the silver from the gold, the alloy is hammered or rolled into thin plates, and digested with dilute nitric acid; this dissolves the silver, but does not act on the gold. When the first solution is poured off, another portion of nitric-acid is added, to effect a perfect solution of all the silver. The gold is now left as a porous spongy mass, and when washed and dried, its quantity is ascertained by weighing. If the quantity of silver in the alloy be small, the excess of gold defends it from the action of the nitric acid; the process called quartation must therefore be resorted to. This consists in adding three parts of silver to the mass, and fusing them together. The silver, then, being in excess, is all separated by the mode before described. The quantity of silver may be ascertained by precipitating it from the solution with muriate of soda. An insoluble substance, chloride of silver, is thus formed, which, when carefully washed, dried, and weighed, will indicate the quantity of the metal, 100 parts of the chloride containing 75¼ of silver. In estimating the commercial value of gold and silver articles, they are said to be so many carats fine: the carat does not denote any specific weight, but a part. Each article is said to contain 24 carats, whatever may be its weight; and the quantity of alloy in carats, or parts, is deducted from the whole. Thus, if an alloy contain 4 parts of inferior metal, it is said to be 20 carats fine; if it contain 6, it is of 18 carats fine, which is the standard of jewellery in England. In France, where every small article of gold is assayed before it is permitted to be sold, a different mode of assay is adopted. The trinket is rubbed on a black touchstone, formed of the black basaltes; black flint or pottery will answer the purpose as well. The jeweller states the quantity and nature of the alloy employed in the article, and the mark it makes on the touchstone is compared with a similar mark made by a needle composed of the same metals and the same proportions. If they correspond in appearance, and are not differently affected by nitric acid or heat, the alloy is pronounced to be of a similar kind to the needle. A great number of assay needles, formed of different proportions of alloys, are necessary for this mode of assay, and long practice and experience in the artist are indispensable. He is guided in the

operation, not merely by the appearance of the stroke on the touchstone, but also by the comparative roughness or smoothness, dryness or greasiness, which is observed in rubbing. The gold coin of Great Britain is 22 carats fine: silver coin is composed of 12½ silver and 1 of copper. An alloy of silver with an inferior metal is assayed by cupellation alone, the process of quartation not being necessary. A given portion is placed in the cupel with a sufficient quantity of lead, and exposed under a muffle to intense heat, until the lead and other inferior metals are vitrified and absorbed by the cupel. The workman is guided in this operation by the appearance of the melted globule. Until the last portions of the alloy have passed through the cupel, the mass appears to be in a state of commotion or ebullition; but when they are absorbed, the silver becomes quiescent, and exhibits brilliant prismatic colours.

ASTRINGENT. A substance possessing a peculiar rough austere taste. This is remarkable in the tincture of galls, bark, the husks of walnuts, green tea, port wine, &c. Leguin first observed that the astringent principle might be separated from the tincture of galls by albumen, with which it forms an insoluble compound. Astringents are sometimes called tannin, and are extensively employed in tanning leather. Astringents are used in medicine to relieve diarrhœa, and as tonics.

ASTROSCOPE. An astronomical instrument, composed of two cones, on whose surfaces are exhibited the stars and constellations, by means of which they are both easily found in the heavens.

ATHANOR. A kind of furnace, which has long since fallen into disuse. The very long and durable operations of the ancient chemists rendered it a desirable requisite that their fires should be constantly supplied with fuel in proportion to the consumption. The athanor furnace was peculiarly adapted to this purpose. Beside the usual parts, it was provided with a hollow tower, into which charcoal was put. The upper part of the tower, when filled, was closely shut by a well-fitted cover, and the lower part communicated with the fire-place of the furnace. In consequence of this disposition, the charcoal subsided into the fire-place gradually, as the consumption made room for it; but that which was contained in the tower was defended from combustion by the exclusion of a proper supply of air. A variety of domestic stoves for burning bituminous coal, on the same principles, but with a different object,—that of burning the smoke, have of late years been introduced and patented. See Stove, and Grate.

ATMOMETER. The name given to an instrument, by its inventor, Professor Leslie, to measure the quantity of exhalation from a humid surface in a given time. A thin ball of porous earthenware, 2 or 3 inches in diameter, with a small neck, has cemented to it a long and rather wide tube of glass, bearing divisions, each of them corresponding to an internal section, equal to a film of liquid that would cover the outer surface of the ball to the thickness of $\frac{1}{1000}$ part of an inch. These divisions are ascertained by a simple calculation, and numbered downwards to the extent of 100 or 200. To the top of this tube is fitted a brass cap, having a collar of leather, and which, after the cavity has been filled with distilled or boiled water, is screwed tight. The outside of the ball being now wiped dry, the instrument is suspended out of doors to the free action of the air. The quantity of evaporation from a wet ball is the same as from a circle having twice the diameter of the sphere. In the atmometer, the humidity transudes through the porous substance just as fast as it evaporates from the external surface; and this waste is measured by the corresponding descent of the water in the stem. As the process goes on, a corresponding portion of air is likewise imbibed by the moisture on the outside, and being introduced into the ball, rises in a small stream to replace the water. The rate of evaporation is nowise effected by the quality of the porous ball, but continues the same, whether the exhaling surface appears almost dry, or glisters with superfluous moisture. When the consumption of water is excessive, it may be allowed to percolate gradually, without dropping, by unscrewing the cap. In a review of Leslie's Meteorology, published in the *Journal of Science*, for Oct. 1822, the writer recommends a vessel of porous earthenware, of a given surface,

filled with water, to be poised at the end of a balance, and the loss of weight which it suffers by evaporation in a given time, to be noted. A thermometer being inserted into the mouth of the vessel, will indicate the temperature of the evaporating mass, and would form, at the same time, a good hygrometer, on Dr. Black's principle, that the degree of cold generated by evaporation is proportional to the dryness of the air. See *Leslie on Heat and Moisture;* also *Ure's Dictionary.*

ATTAR OF ROSES. An essential oil, obtained from roses, of great value, and possessing wonderful odoriferous properties. Gareepon is celebrated throughout India for the beauty and extent of its rose gardens; the rose-fields occupy many hundred acres; the roses are cultivated for distillation, and for making attar. The price of a sieve, or two pounds' weight, (a large quart) of the best rose-water, is eight lenas, or a shilling. The attar is obtained after the rose-water is made, by setting it out during the night, until sunrise, in large open vessels, exposed to the air, and then skimming off the essential oil, which floats on the top. To produce one rupee's weight of attar, 200,000 well-grown roses are required. The juice, even on the spot, is extravagantly dear,—a rupee's weight being sold at the bazaar (where it is often adulterated with sandal-wood oil) for 80 s. r., and at the English warehouse for 100 s. r. or 10*l.* sterling. Mr. Mellville, who made some for himself, said he calculated that the rent of the land and price of utensils really cost him 5*l.* for the above quantity.

ATTRACTION denotes the tendency which is observed in bodies to approach and adhere to each other; it is also sometimes employed to signify the unknown cause of this tendency. It assumes various names, according to the circumstances in which it acts. Thus we have the attraction of gravitation—the attraction of electricity, or electrical attraction—the attraction of magnetism—cohesion, and chemical affinity. The first three of these act at sensible distances, but the range of the other two is too limited to be appreciated by the unassisted senses.

The *Attraction of Gravitation* is the power that upholds the whole planetary system, and retains bodies on the surface of our earth; its action is perceptible at the remotest part of the solar system, and is even manifest among the fixed stars and nebulæ. The laws to which the manifestations of this power are subject will be stated under the article on GRAVITY: at present, we shall confine ourselves to a statement of two experiments connected with this subject, which will clearly evince the existence of this power as inherent, not only in the earth, as a distinct body, but in small, and even detached portions of its surface. The first of these experiments was made by Dr. Maskeline, on the mountain Shebralien, in Scotland. A long plumb-line, attached to a telescope, was suspended successively on the north and south sides of the mountain, when it was found, on each occasion, that the plumb-line did not hang perpendicularly, but was deflected towards the mountain. The other experiment was made by Mr. Cavendish, who, by means of a long and fine silver wire, suspended a slender deal rod, so that it might, by twisting the wire, vibrate freely in a horizontal plane. Small balls of lead were attached to the ends of the deal rod, and, by means of mechanism, larger balls of that metal were carefully brought near to the smaller ones. At each approach of the larger balls, the small ones were sensibly attracted, made to vibrate, and finally arrange themselves in a new position.

Attraction of Electricity is that which occurs between two bodies, one of which is electrified positively, and the other negatively; or one of which is positive or negative, and the other in its natural state. It is probable, however, that this last case is merely apparent, since every body, when brought near to an electrized body, becomes itself electrical by induction. See ELECTRICITY.

Attraction of Magnetism is that which takes place when a loadstone or an artificial magnet is approximated to a piece of iron or steel. It also occurs when the south pole of one magnet is made to approach the north pole of another.

Cohesive Attraction is that which subsists among the minutest particles or atoms of a body, forming them into a solid mass. In gases, this power appears to be wholly deficient, or at least more than counteracted by the effects of an

antagonist power—repulsion. In liquids there are but small manifestations of its existence, but in solids it evinces itself in the most decided and conspicuous manner. The intensity of the cohesive force varies in different bodies, whether solid or liquid,—a circumstance which renders a knowledge of its laws of the greatest importance to mechanics, engineers, and other practical men. For the elucidation of these laws, and the facts on which they are founded, see COHESION.

Chemical Attraction is that which connects the particles of different bodies, and forms them into compound substances. Thus, the power that unites the particles of a mass of copper is called cohesion; but that which causes the union of copper with sulphuric acid, or nitric acid, so as to form sulphate or nitrate of copper, is denominated chemical attraction, affinity, elective attraction, or attraction of composition. Hence we see that chemical attraction and cohesion coexist in the same body. Thus, in the sulphate of copper, one particle of sulphate of copper is connected with another particle by cohesion; while, at the same time, the particles of sulphuric acid are connected with those of copper by chemical affinity. See CHEMISTRY.

AUGER. The name of a very efficient instrument, extensively used by carpenters, and other mechanics, for boring holes in wood. There are several varieties adapted to their peculiar offices, or to the prejudices of workmen. The oldest, or common auger, has a long iron shaft, with a large cross handle at right angles to it, at the top, for enabling the workman to apply both his hands with a considerable leverage, in turning round the shaft, into which is welded a semi-cylindrical piece of steel, from 3 to 6 inches in length, which varies with the size or diameter of the hole made by the instrument; the extremity of this piece is furnished with a sharp tooth, and a cutting edge, which is a small portion of a spiral, and inclined so as to cut as a chisel, the edge operating upon a radical line proceeding from the centre of the hole; and, as it is being constantly turned in a circular direction, the chips of wood are turned out in spiral pieces, and are received into the semi-cylinder above, which has usually one of its longitudinal edges a little sharp to keep the sides of the perforator clean. The upper portion of the shaft is made smaller than the lower, or steel part, for facilitating the escape of the chips, and to enable the instrument to pass the bore freely.

Another instrument, differing from the foregoing, is provided at its extremity with a conical screw, like a gimlet, for piercing the wood the more readily and truly. We have, indeed, frequently noticed in well-made augers of this kind, that no pushing, or rectilineal force whatever is required, the screw keeping them always up to their work.

In a third instrument, chiefly used by shipwrights, that portion of steel, already described, as of a semi-cylindrical form in the common auger, is altogether in this made of a spiral figure, and is found to facilitate the boring materially, besides preventing all liability of the chips becoming jammed or clogged in the tool, which pass freely through the spiral channels, and are discharged externally as the perforation is continued.

A patent for an improvement upon the last-mentioned auger was taken out about ten years ago, by Dr. Church, of Birmingham; but the originality of his invention has been the subject of dispute. In the specification of the patent, the principle of the inventor is stated to consist in forming an instrument of a helical figure, by winding a bar of steel of a "*mixtilinear trapezoid*" shape, round a cylindrical mandrel, by which a circular hole is formed throughout its length, for the insertion of a movable central guide-pin; the upper end of this central pin is screwed into the shank of the auger, and the lower, or working part, is furnished with a wood screw; the office of the latter is to draw the auger into the wood as it is turned, the cutting edges on the helical part at the same time clearing the wood as this auger deepens in the perforation. In grinding and sharpening the edges of the auger, the central pin is, of course, removed for the purpose; and it is obvious that the edges may be ground and sharpened as long as any of the spiral steel bar remains, which renders the instrument extremely valuable, as one, with proper care, may be made to last a man's life-time. This auger, besides, far surpasses all others by the rapidity and facility of its operation.

Auger for making square holes.—It appears that endeavours to supersede the tedious and somewhat difficult process of truly forming square and other shaped holes, varying from the circular, by means of mortice-chisels, were made both in this country, and in America, at about the same period of time. A machine for this purpose, invented by Mr. A Branch, of New York, was described in the Franklin Journal of Philadelphia, in the year 1826. It was stated to consist of an auger, formed like the American screw auger, with the twisted part inclosed in a case or socket, extending from the upper part of the twist to the cutting edge, allowing the small entering screw to project beyond it. The external form of the socket is either square, or otherwise, according to the intended shape of the hole to be bored, a large portion of its sides being cut away to allow the chips to escape. The lower end of the socket is of steel, with a sharp cutting edge, bevelled towards the inside The cutting-edges are not allowed to terminate in right lines, but are made concave, so as to admit the angular points to enter the wood first, this causing it to cut with greater ease, and more smoothly than it otherwise would. The upper part of the socket forms a collar, which works freely on the shank of the auger, just above the twisted part, and is retained in its place by a pin and other appendages. When a longitudinal hole, or mortice, is wanted, two or more augers are placed side by side, furnished with their appropriate sockets, and retained in their places by obvious contrivances." The same journal stated that it was very efficient in its operation, boring a square hole with well defined angles, with nearly the same rapidity as a round one of the same diameter, and forming it with a degree of truth unattainable by the ordinary methods. Upon the publication of Mr. Branch's invention in this country, the editor was invited by Mr. Thomas Hancock, of Goswell-Street Road, to see, in his manufactory, a similar machine, constructed by him several years previous; and having proved its efficacy by boring a considerable number of square holes with great facility, and finding that the angles were perfect, and the holes clean, and exactly uniform throughout, we were induced to make a precise drawing of it, a representation of which, on a scale of one-third (lineal measure) of the original, is given in the subjoined engraving. At *a a*, *Fig.* 1, is a strong iron frame or support, fixed by screw-bits *b b* to the work-bench *c*; *d* is an octagonal iron socket, containing a brass bush, tapped to receive the vertical screw *e e*; to this screw is affixed, by a circular tenon and mortice, the square perforating instrument *f*, which accurately fits and slides up and down through a rectangular hole, in a guide of brass *g*, when the screw *e* is turned by the cross handle at top; so that the square incision is made by direct pressure downwards, at the same time that the revolving centre-bit *m* cuts out a completely round hole, the chips rising up and passing out at the two open sides of the square cutter; *h* represents a piece of wood in the act of being bored, the dotted lines showing the depth to which the perforation has reached; a small piece of wood *i* is placed underneath, to prevent injury to the cutting-tool, by coming in contact with the cross iron plate *k*; the bolts *b b* passing through *i* as well as *k*, secure both firmly to the bench *c*. *Fig.* 2 exhibits the cutting part of the instrument, separately, on an enlarged scale, with the lowermost portion in section; the tenon *i* is inserted into a cavity in the screw *e*, *Fig.* 1, and made fast by a cross pin, which goes through both; by this arrangement the instruments can be readily exchanged for others of different dimensions; the lower extremity of this revolving piece is formed into a centre-bit *m*, which, owing to the collars *n n*, cannot ascend or descend without the square instrument, which accurately cuts out the angles beyond the range of the circular incision made by the former. The square cutting-tool is made of a bar of steel, with a hole drilled out of the solid, in the manner shown by the end view, *Fig.* 3, and the edges are then formed by filing and grinding them to the bevels, or angles, shown in section by *Fig.* 2. *Fig.* 4 represents a similar view of the end of the instrument, but with the centre-bit in its place. It will be readily perceived that a square tool, by repeating the incisions side by side, close together, may be made to produce a cavity of the figure of any rectangular parallelogram of any length or breadth, larger than the instrument employed. The same effect may likewise be produced by a

single operation, by arranging a series of centre bits or circular cutters, side by side, with toothed wheels at their upper extremities or axes, giving into each other, which will cause them all to bore simultaneously ; a single external rec-tilineal cutter, embracing all the centre bits, would then suffice for the purpose. In like manner, any acute or obtuse-angled figure, any polygon, or any figure with curved sides, might be made of any size whatever. By the construction of the machine described, it will be perceived that it is necessary, in changing

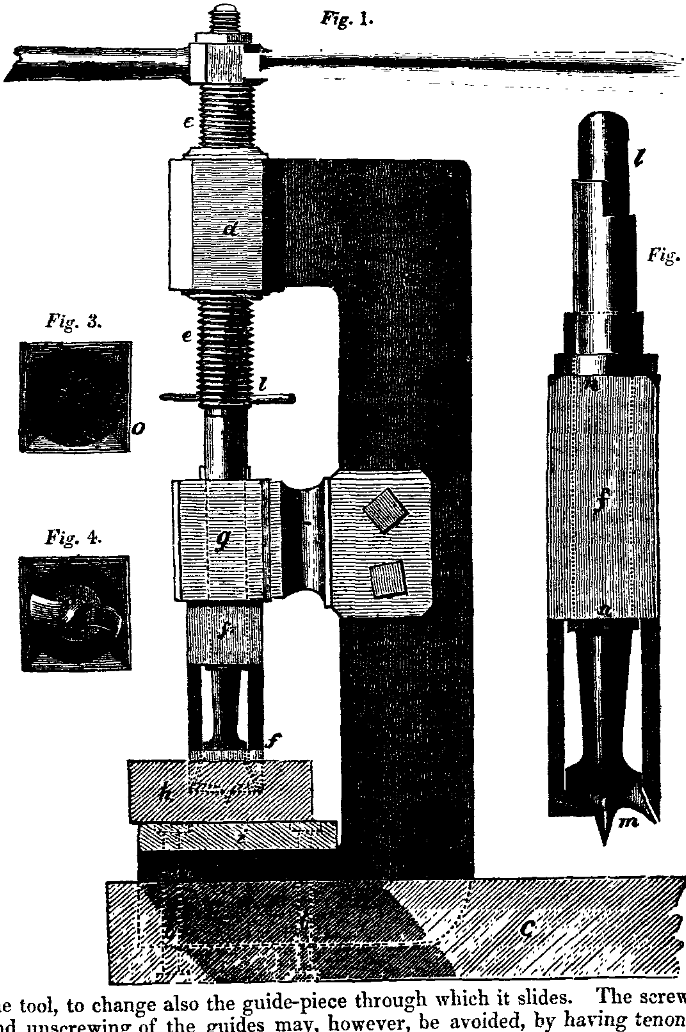


Fig. 1. *Fig.* 2. *Fig.* 3. *Fig.* 4.

the tool, to change also the guide-piece through which it slides. The screwing and unscrewing of the guides may, however, be avoided, by having tenons in the latter of an uniform size, to fit in a mortice in the upright iron frame; and in manufactories where a great variety of mortices have to be made, we would suggest another mode, in which the trouble of changing the guides would be still less : it is to have a guide *wheel* turning horizontally upon the upright bar *a* as its axis ; on the circumference of the wheel should be made a series of apertures, corresponding with the form of the tools and of the mortices required. By this arrangement, indeed, most of the tools might be left in the guide-wheel,

ready to bring any one of them into action under the screw, by just turning the wheel round. In those branches of business wherein a great number of mortices are required of one size, a machine of the kind described will be most valuable; and as it requires no skill in the operator, a boy, or a mere labourer, will perform the operation as well as the most experienced workman. Chair makers might adapt a machine on this principle to their work with important advantages; wheelwrights, also, for morticing out their naves. In thè large workshops of carpenters, an instrument of the kind described would forward a great deal of work in framing, as it might easily be so modified as to perform the office also of a cramp to draw the jointed parts of the work into close contact. It is to be observed, that Mr. Branch's instrument is the same in principle as Mr. Hancock's, but that it will require some modifications to render it as efficient an instrument.

AURUM MUSIVUM, or MOSAICUM, is a combination of tin and sulphur, having the appearance of bright gold in powder. It is used by japanners, and for varnished works, as snuff-boxes, tea-trays, &c., also to statue and plaster figures. The usual process of preparing it is as follows: amalgate 12 parts of the purest tin with 3 parts of mercury; the amalgam is then triturated in a stone mortar with 7 parts of the flour of sulphur, and 3 parts of muriate of ammonia. The mixture is next put into a matrass, and the whole exposed to a gentle sand heat, until no more white fumes arise. After this, the heat is somewhat raised, and cinnabar sublimes, together with some oxygenated muriate of tin, while at the same time the remaining tin and sulphur unite, forming the aurum musivum, exhibiting a golden yellow, and flaky scaly matter of a metallic lustre. The principal point to be attended to is the regulation of the fire; for if the heat be too great, the aurum musivum fuses to a dark-coloured sulphuret of tin. The process of the Marquis de Bouillon, as described by Chaptal, differs from the foregoing in the proportions; and the experiments of the latter chemist are also worthy of notice. The marquis's process consisted in amalgamating 8 oz. of tin with 8 oz. of mercury, and mixing with this 6 oz. of sulphur, and 4 oz. of muriate of ammonia. This mixture is to be exposed for three hours to a sand heat, sufficient to render the bottom of the matrass obscurely red hot. Chaptal, however, found that if the matrass containing the mixture were exposed to a naked fire and violently heated, the mixture took fire, and a sublimate was formed in the neck of the matrass, consisting of the most beautiful aurum musivum in large hexagonal plates. Bergman mentions a native aurum musivum from Siberia, consisting of tin, sulphur, and a small proportion of copper. According to Dr. John Davy, the aurum mosaicum, or mosaic gold, consisted of 100 tin, and 56.25 sulphur. Berzelius makes the proportions 100 tin, and 52.3 sulphur. The mean of those results, viz. 100 tin + 54.2 sulphur, may therefore be regarded as the correct proportions. A few years ago a patent was taken out by Messrs. Parker and Hamilton, for an alloy of copper and zinc, which they termed the true mosaic gold. The specification directs that equal quantities of copper and zinc are to be melted at the lowest temperature at which the former will fuse, when they are to be well stirred and mixed together; small quantities of zinc are then added by degrees, until the alloy assumes the desired colour. It is essential that the heat should be as low as possible, to prevent the rapid evaporation of the zinc. The alloy first assumes a yellow colour; the addition of more zinc turns it first to a purplish tint, which ultimately becomes perfectly white, which is the colour it should have when in a state of fusion. It may then be cast into ingots for use; but it is preferable to cast the alloy, in the first instance, into the forms required, as a portion of the zinc flies off on remelting.

AUTOMATON. In the strict sense of the word, a piece of mechanism in which the effects are produced by some inanimate force contained within it; the word is, however, more commonly used to signify a piece of mechanism made to resemble some animal, whose motions it imitates by means of internal machinery, which being concealed from the spectator, gives it an apparent power of acting by volition. Numerous descriptions of autómata of this class are to be found in the writings of various authors, amongst the most admirable

of which may be ranked the automaton flute-player of M. Vaucauson, of which the ingenious inventor published a very full description. It is to be regretted that this description was not, at least as far as we can find, accompanied by drawings, which were desirable for the better elucidation of the subject. We are, on this account, induced to relinquish our desire to give place to it here, and must content ourselves merely by observing, that the figure was of the natural size, and that the different notes were produced by a current of air, urged by bellows contained within the pedestal on which it was placed, and passing through the lips into a flute, the holes of which were stopped by the motion of the fingers of the figure, whose tongue and lips were likewise movable, and aided in the modulation of the sounds. The same artist also subsequently produced another figure, representing a Provençal shepherd playing on a pipe, and beating a tabor, which he describes as attended with greater difficulty in the execution than the preceding one. But of the many inventions of this description, none have attained such celebrity as the automaton chess player of Baron de Kempelen, of Vienna. It was a figure, representing a Turk seated at a square table, or chest, the top of which formed the chess-board, on which the automaton made the various movements. It was exhibited in most of the leading cities of Europe, but the principles of its construction were never disclosed; nor, although it had been frequently asserted by many persons that the whole was a trick, and that the motions were produced by an individual concealed within the figure, various ways in which this might be effected being pointed out, was any examination permitted sufficiently strict to lead to the exposure of the deception, if any was practised. The exhibiter affected great apparent openness in displaying the various machinery of wheel-work and levers which the interior certainly did contain; but this might have been placed there as much for the purpose of aiding in a deception, as for any useful object. When the writer saw the figure, during its exhibition in the Haymarket, in 1816, it was shown in a manner which precluded any close examination; the spectators were ranged upon a series of rising benches, at a considerable distance from the figure; the attendant first opened several doors in the machine in succession, to show that no person was concealed within it; the doors being then closed, the machine was wheeled round the room, that it might be seen there was no connexion with the floor. The game then commenced; the person who played against the figure was seated at a small table, railed off at some distance from it, and had before him a chess-board, with the full complement of black and white chess-men; the chess-board before the figure was furnished in a similar manner. When the player made a move, the attendant made a similar move upon the chess-board of the automaton; and when the latter moved, the attendant repeated the move upon the chess-board of the person playing. Without pretending to explain the manner in which the motions of the figure were produced, we think that from the very nature of the thing we may assert that they were not effected by the mechanism contained within it, for we consider mere machinery utterly incompetent to produce the requisite effects. We shall proceed to state the grounds on which we have come to this conclusion. Any variety of movements which are required to follow each other in a *certain* order of succession, may doubtless be produced by mechanism, as, for instance, the striking parts of a clock, or, more especially, in the calculating machine of Mr. Babbage; nor is it necessary that the succession be in any *regular* order, provided, as in the kaleidoscope, the results may be altogether arbitrary, or the effect of accidental combinations; but the moves at chess, although they follow no *regular* order of succession, for they may be infinitely varied, may yet not be made indiscriminately, but depend upon circumstances beyond the control of the machine, such, for instance, as the moves of the antagonist, or the number and position of the pieces on the board. From these considerations, we conclude either that the motions are governed by some person from without, by means of some ingeniously contrived and concealed mechanism, or by some person secreted within the machine. The author of a pamphlet on the subject, published in 1821, maintains the latter supposition to be the fact; and by the aid of several diagrams, shows that not merely a dwarf, as was at one time supposed, but even an ordi-

nary-sized man, might be concealed; and this opinion is further corroborated by the proprietor refusing to exhibit the figure in action, with the several doors of the machine open, when requested to do so by a scientific gentleman, whose object was to satisfy himself and some friends that the movements were really produced by machinery.

AXE. A heavy steeled instrument, employed for cutting down trees, and by carpenters and other mechanics for cutting large masses of wood, when attention to much exactness is unnecessary, or the saw cannot be conveniently used. It consists of a broad blade of iron, with a loop, or eye, for the reception of a long wooden handle, which passes through it at right angles. The cutting-edge is steeled to about an inch in breadth and to the back of the eye, in some kinds, is welded a solid lump of steel, called the poll, which serves the carpenter as a very efficient heavy hammer for driving spikes, forcing up large tenons, mortices, &c. The form of axes are very various, being adapted to peculiar trades, and accommodated to provincial prejudices. The most perfect instruments we have seen of this kind, are the productions of several tool-smiths, distributed over the county of Kent. One we recollect at Seal, another at Seven Oaks. We have thought it proper to mention this fact, as the article alluded to has a very decided superiority over those made in our great manufacturing towns. The smaller kind of axes, weighing under 2 lbs. each, are denominated hatchets.

AVIARIES. A place appropriated to the feeding and rearing of birds, sufficiently extensive to allow them scope for flight. The inclosure is usually made of net-work, duly supported, but preferably of wire-work. The interior is sometimes provided with trees, and other objects of nature; and the floor covered with turf, to avoid the appearance of dirt.

AXIOM. A self-evident truth, or one that neither requires nor admits of a proof, because it cannot be made plainer by demonstration; as, for instance, "a whole is greater than a part."

AXIS, in Geometry, is the straight line about which a plane figure revolves, so as to produce or generate a solid; or it is a straight line drawn from the vertex of a figure to the middle of the base. The *axis of a circle or sphere* is a straight line passing through the centre, and terminating at the circumference on the opposite sides. The *axis of a cone* is the line from the vertex to the centre of the base. The *axis of a cylinder* is the line from the centre of the one end to that of the other. *Transverse axis*, in the ellipse and hyperbola, is the diameter passing through the two foci, and the two principal vertices of the figure. In the hyperbola it is the shortest diameter, but in the ellipse it is the longest. *Conjugate axis*, in the ellipse and hyperbola, is the diameter passing through the centre, and perpendicular to the transverse axis. It is the shortest of all the conjugate diameters.

AXIS, in Mechanics, is a line about which a body may turn: by workmen, the term axis is generally considered to imply a cylindrical bar, around or upon which a wheel, or other body, rotates.

AXIS, in Peritrochio, a pedantic name which has been given to one of the mechanical powers, commonly called the wheel and axle.

AXLE-TREE. The pivot, or centre, upon which a carriage wheel turns. They were formerly made of wood, and, we believe, are to this day, in some parts of the country, but are now generally constructed of iron. Numerous improvements have, of late years, been introduced in their construction, some of which we shall notice, after a few words upon their more ancient construction. One very old plan was to fix the axle immovably into the naves of both wheels, the axle revolving in bearings attached to the carriage; by this means the nave was less weakened, and the wheels had less play, than if the axle-tree was fixed to the carriage, and worked in a box in the nave, but were inconvenient in turning, as both wheels revolved with the same speed; the axle-trees were, therefore, attached to the carriage, and each wheel revolved separately upon its axle, by which means, in turning short, the inner wheel could remain stationary, and serve as the centre of motion to the carriage. Axles were originally made straight, their arms lying in the same horizontal plane, and

the wheels, of course, perpendicular to them; but as carriages came more generally into use, more room was required; and the roads being narrow and bad, and the wheels being, therefore, required to keep in the beaten track, recourse was had to splaying the wheels, by bending the axles downwards, by which means the upper part of the rims of the wheels were further apart than the lower; and this method continues in general use to this day, although the improved state of the roads no longer requires it, and the draft is made heavier, and the roads more quickly destroyed by it. The objects chiefly aimed at in the various improvements in axle-trees, is to diminish the friction by decreasing the amount of rubbing surface, and by carefully excluding dirt from the boxes; in keeping them well oiled, and to attach the wheel so securely as to avoid the fatal consequences arising from the linch pin falling out. We shall now proceed to describe two constructions of axle-trees, invented by Mr. Mason, of Margaret Street, Cavendish Square; the first adapted to what are commonly called Collinge's, or patent axles; and the second, to the description of axles called mail-coach axles. The first construction is shown in *Figs.* 1, 2, 3, and 4.

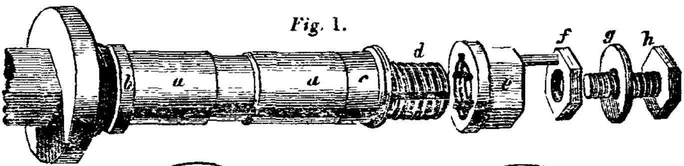


Fig. 2.

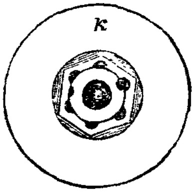
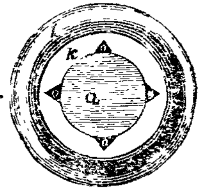


Fig 3.



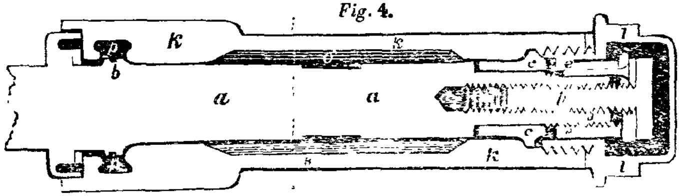
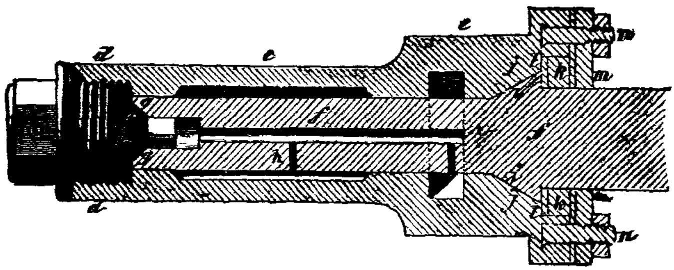


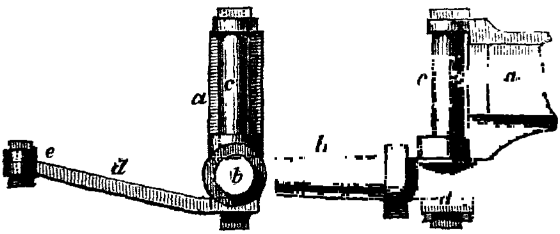
Fig. 1 represents a perspective view of the axle, with its principal appendages arranged in a line to show the mode of their application. *Fig.* 4 represents a longitudinal section of the axle-tree, with its several appendages screwed up into their respective places, and lying inclosed in the box peculiarly constructed for that purpose. *Figs.* 3 and 4 give sections of certain parts of the axle-tree and box, hereafter to be described. The like letters refer to similar parts in each figure. *a a*, the main part of the axle-tree; *b*, a fixed shoulder; *c*, a movable shoulder formed upon a metal collet, and rendered capable of being slided backwards and forwards, but not of turning round. This collet is adjusted and retained in any required situation, as will be presently shown; *d* is a screw formed upon the outer end of the axle-tree; *e* is a nut, hexagonal on the outside, and screwed in the inside to fit *d*. Around the inside of the hexagonal nut are cut longitudinal, and at equal distances, six semicircular grooves (as partly shown in *Fig.* 1), but more distinctly seen in the section *Fig.* 2; the screw *d* has, likewise, two similar grooves cut into its thread, and so placed with regard to each other, that when one groove corresponds with one of the grooves in the nut, the other groove shall be midway between two

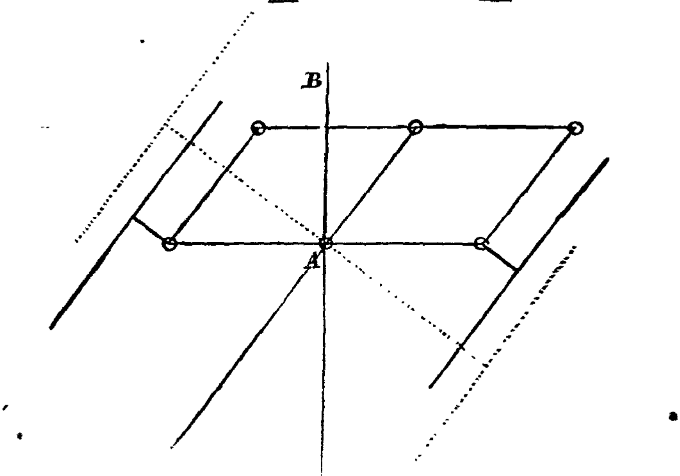
other grooves in the nut; and, in order to fix this nut in the required position, a cylindrical pin, which is rivetted to the hexagonal plate *f*, is inserted into one of the holes formed by the union of a groove in the nut with a groove on the axle, which entirely prevents any rotation of the nut so long as the pin remains in the hole; and there being two grooves in the axle, and six in the nut, the position of the nut may be regulated to $\frac{1}{12}$ of a turn, equal to $\frac{1}{120}$ of an inch, if the screw has 10 threads per inch. To prevent this pin coming out, a collar of leather *g* is first put on the long hexagonal-headed screw *h*, when the latter being screwed into the internal screw of the axle-tree (seen at *Figs.* 2 and 4), the whole is thus made fast. Having thus described the construction of the axle-tree, it remains for us to explain the construction of the box, which we have put in section in its proper place, around the axle-tree in *Fig.* 4. *k k k k* show the cylindrical parts of the box, with a cap *l l* screwed on its outer extremity, which serves to contain oil for those parts of the axle-tree which are contiguous. *o o* are long grooves also for oil; two of these are brought into view in the longitudinal section, *Fig.* 4; but there are four of them, as may be seen in the transverse section at *Fig.* 3, which section is made where the dotted line divides *Fig.* 4. *p p* is another reservoir for oil. The whole of the arrangements in this invention appear to us excellent. The quantity of oil contained in the reservoirs, and which is constantly circulating round the axle, is greater than in any other wheel-box that we recollect, and must greatly reduce the friction. The ease and safety with which the wheel may be let out when travelling on bad roads, is another great advantage, and which we believe to be peculiar to this axle, whilst the method of securing the wheel upon the axle seems to leave nothing to be desired on that head. This last part of the invention may be also usefully employed in various parts of machinery, as where wheels run upon studs, or pivots, &c. The figure beneath represents Mr. Mason's improved mail



axles, although some parts of the invention are applicable to the patent axles. *a* is the box cap, which constitutes at the same time an oil cup with a conical end *c*, which fits into the conical part *g* of the axle *f*; when that is fitted into the box *e* and the cup screwed into *d*, the oil then flows through an aperture in the end of the cup *c* into the hollow part of the axle, and passes out to the box at an aperture *h*, supplying the long reservoirs in the interior of the box. There is, likewise, a very small groove cut longitudinally on the axle, extending both ways from *h*, so that the oil may be readily distributed over all the bearing parts. This lubricating arrangement is, evidently, applicable to both kinds of axles, but the other part of the contrivance, which has for its object the better security of the wheel, and the prevention of end-play, so as not to allow the escape of oil from the box, nor the admission of dust, or other impurities into it, applies exclusively to the mail axles, or those which are kept in the box by means of screws at its inner end. Three wrought-iron screws are cast into three legs on the box, two of which are shown in the figure at *n n*. When the axle is introduced into the box, the conical part *i* fits the conical part *j*, and tends to preserve the leather collar between *i* and *k*, while the loose plate *m* fits upon, and is firmly secured by, the screws *n n* to the end of the box, and thus the box is kept in its place by the collar *k*, which works in the recess *l*, and the wheel is prevented from coming off by the plate *m m*.

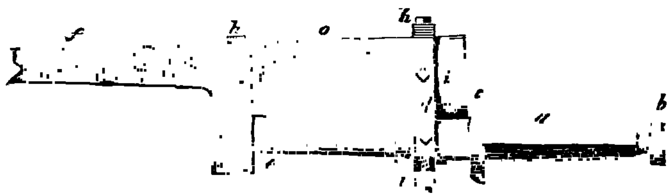
Formerly, this plate was fastened by short screw-bolts passing through it and the legs of the box, a method which was found defective on account of their liability to shake loose by the constant jarring of the coach. To remedy this, and to facilitate the removal of the wheel when desirable to take it off, the back plate was fastened by long bolts passing through the nave and screwed on the outside; but this, too, was found to be objectionable, on account of the injury caused to the nave by the bolt holes, and their occasional removal, when the wheel required taking off; and to remedy these defects, is the object of the invention which we have been describing. An objection to the present mode of locking the fore wheels of four-wheeled carriages from the centre, is, that in sharp turns, the fore-wheels are brought so nearly in a line with the perch, that the coach has little better than three points of support, and is, therefore, very liable to be overturned. Another inconvenience arising from this method is, that it requires the fore-wheels to be made much smaller than the hind ones, which greatly increases the draft, and has, at the same time, an inelegant appearance. These objections are obviated by a construction, for which Mr. Ackerman took out a patent in 1816, the principle of which is as follows: The fore axle-tree of the carriage does not turn, but is fixed to the perch in the same manner as the hind one; each of the fore wheels revolve upon one end of a short arm, the other extremity of which is turned up at a right angle, and turns in a hinge joint at each extremity of the fixed axle-tree; from the back of each of the short axles, a lever projects, and the coach-pole being carried back beyond the pin in the fixed axle-tree, an iron bar connects the extremities of the two levers, and of the coach-pole, so that when the coach-pole turns upon its fulcrum, the short axles turn upon their upright arms as





centres, and if the length of the connecting bar be equal to the distance between the vertical arms of the axles, the two wheels will always stand parallel to each other; but by varying the length of the connecting bar, the inner wheel, in

turning, may be made to perform a shorter curve than the outer one. The cut represents one of these arms, *Fig.* 1 being a front view, and *Fig.* 2 a side view; *a* is a portion of the fixed axle-tree; *b* the horizontal arm upon which the wheel revolves; *c* the vertical arm; *d* the lever; *e* connecting bar. In the diagram, *Fig.* 3, the dotted lines represent the position of the fore wheels when locked to the utmost extent; and the other lines, their position in the same circumstances, with axles on Mr. Ackerman's plan, from which it will be seen that the latter afford a much wider base to the carriage than the former; the wheels may also be made of nearly the same diameter as the hind wheels, without hanging the body of the carriage higher. A B is the line of the perch. Patents for axle-trees upon the same principle have since been taken out by Miss Knowles, and by Mr. Mason, varying slightly in the details. There have been many plans proposed for diminishing the friction at the axle by means of anti-friction rollers; but, from the experiments made upon rail-roads, of the resistance of running wheels thereon, as compared with those on common roads, it appears, the amount of friction of the axes of wheels made in the common way, was so extremely trifling in comparison with the resistance at the peripheries, that it became absolutely impossible to gain any practical advantage of moment by such a reduction of the axles as they are susceptible of. It should be borne in mind, that the weight of the carriage must be supported on some of the rubbing, or revolving, parts; and these parts being already, comparatively, very small, their surfaces cannot be much reduced without impairing the requisite strength. By anti-friction rollers, we only transfer the friction, without materially lessening it; whilst we incur complexity, increased expense, and greater liability to derangement. For these reasons, we shall notice only one out of the many contrivances on this subject; it is the invention of Mr. Spong, and is selected as being the simplest in construction. *a e* is the revolving axle-tree made square



at *a* for inserting into the nave of the wheel, to which it is made fast, by means of the nut *b* screwing it close up to the shoulder *c*. The circular part of the axle revolves in two bearings; one in plummer blocks at *d*, regulated by screws at *l*; the other at *e*, in a solid piece projecting from the axle-tree *f*. The thick end of the axle at *o*, carries an anti-friction roller *k*, which turns on a short pivot, or axis, at *i* (shown by white dots). Oil is applied to the bearings and axis, by means of perforations at *h h*, which are closed by screw stoppers.

From an account of some experiments made by Mr. H. R. Palmer, now engineer to the London Dock Company, it would appear that the forms of the cavities, or interstices, through which the lubricating matter is applied to the axes of wheels, is of considerable importance. During a succession of experiments occasionally for many months, he invariably perceived that when fresh oil was applied to the axles of the carriage, *the resistance was increased*, and it required the ordinary motion of the carriage for several days to restore the resistance to its usual standard. No other presumption occurred to account for this fact, than the possibility of the oil being better adapted for its office after being some time exposed to use. It was suggested to him that the oil became thickened, or less fluid, after exposure to the air, and was therefore better able to resist the contact of surfaces. In order to prove this, he thickened some oil artificially, by the admixture of a small quantity of bees'-wax, but the appearances were the same as before. It then occurred to him, that there was not sufficient play, or difference of diameters, between the axle and

the nave in which it worked; he therefore had the axles slightly reduced. On again measuring the resistance, he found circumstances as before, but differing in amount, the resistance being slightly increased. He was by this time convinced that the quantity, rather than quality, of oil, occasioned the appearances; to prove which, the axles were made perfectly clean, and then simply moistened with oil by the finger, previous to inserting them in the wheel. In this state the resistance was again measured, and found to be *similar to the standard usually observed* after the carriage had been some days in motion, as before described. It being, then, proved that the *quantity* of oil occasioned the difference of resistance, the following solution of the manner in which the additional quantity could produce such an effect, appeared reasonable. Let A B C D, *Fig.* 1, represent the circle of the hole in the nave of the wheel, and E C the

Fig. 1.

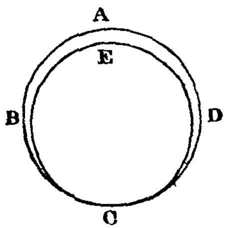
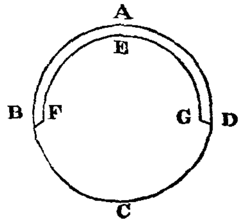


Fig. 2.



section of the axle. The circle E C touches A B C D only in the point C. A very acute angular space then remains between A E and C on either side of E C. If that space be filled with oil, the oil may be considered as a wedge, and if the outer circle be set in motion, that wedge will endeavour to pass the point C. But it cannot pass in its present form without raising the circle E C; but E C having the weight of the carriage upon it, would resist its passage. Now this continual and unsuccessful endeavour to pass the point C will occasion an impediment to the motion. To put this solution to the test, the axles were formed as in *Fig.* 2. A B C D is the hole in the nave as before, and E F C G the section of the axle. The lower semicircle of the axle here corresponds with, or is parallel to, the outer circle, but no further, because *if it corresponded throughout the circle, the axle would be liable to jamb, as other experiments have proved.* The coincidence then ceases abruptly, as at B F G D, and the space above which contains the oil is not angular, but the quantity of oil which is to pass toward the lower semicircle is determined at B or D. On measuring the resistance with the axle thus formed, he found it not increased by any quantity of oil that might be inserted; but by dispensing with the angular space, and consequent wedge-like action of the oil, *the resistance was one-tenth less than the former standard.* In cases where the difference of diameters is considerable, he does not apprehend the obstruction from the quantity of oil would be of consequence; but it is desirable to make the bearing surfaces nearly to correspond, to obtain a greater *width* of touching surface, and the more perfectly to govern the motion. The form of axle just described is, in fact, the converse of a well-made plummer block, used in machinery.

AZIMUTH, in Astronomy, is an arch of the horizon intercepted between the meridian of a place, and the azimuth, or vertical circle, passing through the given object; or it is the angle formed at the zenith by the meridian and vertical circle. The azimuth of the sun, or a star, at the time of the equinox, is found by the following proportion. As the radius is to the tangent of the latitude of the place of observation, so is the tangent of the sun's, or star's, altitude, to the cosine of the azimuth from the south.

AZIMUTH, Magnetic, is an arch of the horizon included between the magnetic meridian, and a vertical circle passing through the object. It differs from the true azimuth, on account of the variation of the magnetic needle. The magnetic azimuth may be determined by observations with the azimuth compass, and the true azimuth calculated therefrom.

AZOTE, or NITROGEN. The phlogisticated air of Dr. Priestley. It contains four-fifths of atmospheric air, and one-fifth of oxygen. See CHEMISTRY, and NITROGEN GAS.

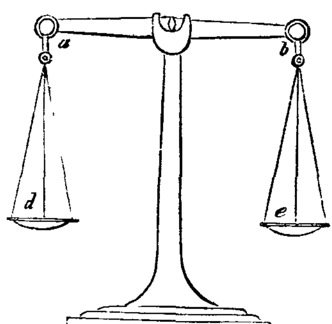
AZURE. The blue colour of the sky, and the name given to a celebrated Egyptian pigment, which has preserved its brilliancy of tint for upwards of seventeen hundred years. The late Sir Humphrey Davy, who experimented on the constitution of this substance, found that it might be easily and cheaply imitated. Thus take 15 parts of the carbonate of soda, 20 of powdered opaque flints, and 3 of copper filings; strongly heat them together for two hours, when a substance will be produced, which, when powdered, affords a fine deep-coloured blue pigment, closely resembling the Egyptian azure.

AZURE-STONE, or LAPIS-LAZULI, is a massive mineral, of a fine azure blue colour. Lustre, glistening. Fine grained, even fracture. Scratches glass, but scarcely strikes fire with steel. Opaque, or translucent, on the very edges. Easily broken. Spec. grav. 2.85. It consists, according to Mes. Clement and Desormes, of 34 silicia, 33 alumina, 3 sulphur, 22 soda, loss 8,=100 parts. The finest specimens are brought from Persia and China. It is from these stones that the beautiful unchangeable blue pigment, *ultramarine,* is prepared. The stones are first made red hot, then thrown into water to cool them suddenly, which enables them to be easily pulverized. The fragments are then reduced to a very fine powder in a mortar, and intimately combined with a varnish composed of resin, bees-wax, and linseed oil. It is then of the consistence of paste, and is put into a linen cloth, and repeatedly kneaded with hot water. The first water is thrown away, the second gives a blue tint of the first quality, and the third yields one of less value. This processis founded on the property which the colouring matter of the lapis-lazuli has of adhering less firmly to the resinous cement, than the other matter with which it is combined

B.

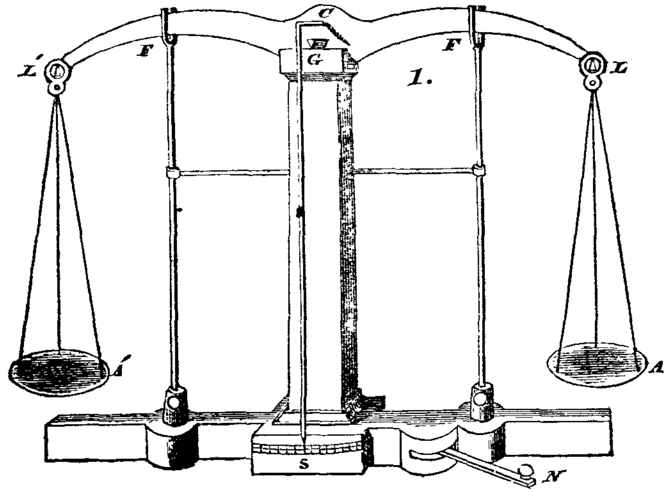
BAKING, in its true sense, implies the process of applying a dry or scorching heat to any substance in a close vessel or chamber; but the term is generally understood to mean the art of preparing bread, for which see BREAD, OVEN, &c.

BALANCE. A simple machine, in which the lever is employed to determine the equality or difference of two given weights. Balances are of various kinds, differing in their form, and in the perfection of their construction, according to the nature of the objects for which they are employed. The common balance or scales are well known to consist of a lever or beam *a b*, turning on its axis in a vertical plane, and having two dishes or scale-pans *d e* suspended at its two ends. The distances between the centre of the beam and the extremities *a* and *b* are made as nearly equal as possible: hence it is clear, from the nature of the lever, that the weights placed in the two scales will be equal to each other when the beam rests in a horizontal position. Although, theoretically speaking, the balance is exceedingly simple, consisting merely of a right line turning on its centre, yet in practice it becomes a matter of considerable difficulty



to approximate its construction to that perfection which theory points out, and which the nicer operations of philosophical research demand. Although it is not necessary on all occasions to use a balance capable of detecting differences in weight equivalent to the $\frac{1}{2000}$ of a grain, yet the more perfect our model is, and the nearer we approach to it, the greater chance there is of obtaining the object of our search, viz. an exact indication of the weight of any given substance. In the most perfect balances, one of which is represented in the annexed engraving, the beam L L is a bar of tempered steel, so strong as not sensibly

to bend with the weights usually placed in it. If G is the centre of gravity of the beam, the arms G L G L should be of precisely the same length. At the extremities, silk cords of the same length and weight support the scale-pans A A, which are also equal. That the slightest motion of the beam may be distinguished, an index S C is attached to the beam exactly perpendicular to it, and in the same plane with the centre of gravity. The whole is sustained on an

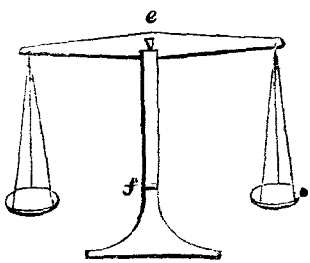


axis perpendicular to the beam at C; and in order that the line around which the beam turns may not change its place, and thus vary the lengths of the arms, the axis is formed below into a sharp knife edge of hardened steel, and moves on planes of polished crystal, agate, or other hard substance. Now if a perfect equality were established between the parts of the balance on each side the centre G, an equilibrium would naturally occur when the beam L L′ was in a horizontal position; for the centre of gravity of the whole would then be in the same vertical line as the point C; hence if weights were placed in the scale, and the beam retained its horizontal position, we might infer their equality. But an experiment of this kind may be possible or not, according to the position in the vertical line of the points C and G. If the centre of gravity G coincided with the centre of motion C, the beam would rest in any position into which it might be thrown. Or if the centre G were above the centre C, the beam would remain horizontal when placed so, but its equilibrium would be unstable, and the least additional weight to either side would cause that side to descend indefinitely. But if the centre of gravity be below the centre of support, then, if the horizontality of the beam be deranged, it will be recovered after a succession of oscillations of continually diminishing amplitude. The delicacy, or stability, of the beam, will depend, in a great measure, on the distance between these two points. Thus, if G be much below C, a considerable weight will be required to turn the beam, but it will soon regain its state of rest. On the other hand, if the point G be only a short distance below C, a slight additional weight will cause the arm to descend, but it will be longer in regaining its quiescent position. The sensibility is increased by lengthening the arms, diminishing the distance between the centre of support and centre of gravity, and lessening the weight of the beam, and the quantity of matter to be weighed. The stability also increases with the weight, and the distance between the two centres. As another step towards the perfection of the balance, we must be careful that the centre C and the knife edges that support the scale-pans at L L, be in the same right line. If this be neglected, the beam becomes

a bent lever, and the weight of the body will appear to vary with the position of the beam. The great difficulty of attaining an exact equality in the length of the arms of a balance, renders it almost hopeless to attempt to obtain the exact weight of any mass of matter by this means. It is fortunate, therefore, that there is a method of weighing which will enable us to dispense with one of these, and uot the least difficult of attainment. The method of double weighing, introduced by Borda, renders the equality in the length of the arms a matter of indifference. To ascertain the weight of a body by his method, we place the body in one scale, as A, for example, then exactly counterbalance it by small shot, sand, &c. placed in the other scale A, till the index points to O on the scale at the foot of the pillar supporting the beam. The body is next carefully removed from the scale A, and its place supplied by known weights, until the beam again stands horizontal. The weights then in the scale will indicate the weight of the body. As the weights, and the body to be weighed, have both been placed in the same scale, and, consequently, at the same distance from the centre, it is manifest, whatever may be the length of the arms, or their weight, that the true weight of the body has been ascertained. That this method may be completely efficient, only two conditions are required to be fulfilled. The one is, that the distances between the centre C, and the points L L, continue the same during the operation of weighing; and the second is, that the balance be exceedingly sensible, *i. e.* that it turn with the smallest possible quantity of matter. The first of these conditions is fulfilled by making the points L and L′, of hardened steel, and sharpened to a knife edge, like the point C, as, in this case, the motion of the beam will not sensibly change the points of support, and, consequently, the distance between C and L will be accurately preserved. The second condition is to make the balance sufficiently sensible, which is accomplished by attention to the centre C, diminishing its friction as much as possible. For this purpose, the planes that support the knife-edge are highly polished; and, in order that they may be preserved in their original state, the beam is not suffered to rest upon its centre but when in actual use. To sustain it when not in use, the two forks, F F are employed, which raise it from its support, and preserve it in a horizontal position. These forks are movable by means of the handle N. When the balance is to be used, the forks are lowered, and the beam set at liberty; and, as soon as the observation is completed, the forks are raised, and the beam elevated from its supports till again required. To preserve the balance from the motions that would result from currents of air, it is sometimes inclosed in a glass case, having apertures in it large enough to admit the substance to be weighed to be put into the pans. When the instrument is not in use, it is recommended to place within the case a small saucer filled with muriate of lime, or some other substance of strong hygrometric power, to absorb the moisture that would otherwise settle on the instrument, and destroy its polish by oxidation. In order to ascertain the value of a balance, the scales may be removed from the beam, to see whether the beam balances without them. They may then be put on again in opposite sides, and tried. Equal weights should then be placed in each scale, and afterwards changed to the opposite one; and if the beam maintains its horizontal position during all these trials, it may be considered as accurate. The utility of good balances for weighing different substances, is not limited to the accurate performance of delicate experiments, but applies also to the saving of much time in weighing, when a smaller degree of accuracy is required. If a pair of scales, loaded with a certain weight, be barely sensible to one-tenth of a grain, it will require a considerable time to ascertain the weight to that degree of accuracy, because the turn is small, and must be observed several times over; but, if a balance were used that would turn with the hundredth part of a grain, and the weight was not required to any greater accuracy than the tenths of grains, a single tenth of a grain, more or less, would make so great a difference in the position of the beam, that it would be seen immediately. If a balance be found to turn with a certain additional weight, and is not moved by any smaller weight, a greater sensibility may be given to it by producing a vibratory, or tremulous motion, in its parts. If the edge of a blunt saw, file,

or similar instrument, be drawn along any part of the case, or support, of a balance, it will produce a jarring which will diminish the friction on the moving parts so much, that the balance will turn with a third or fourth of the addition that would otherwise be required. In this way, a beam that would barely turn with one-tenth of a grain, may be made to turn with a thirtieth or fortieth of that quantity. The improvement in the balance has progressed with the general advance of the mechanic art, to such an extent, that it would seem impossible to attain a higher degree of perfection than that which has been attained in the construction of some modern balances. Mr. Read's balance, described in the sixty-sixth volume of the *Philosophical Transactions,* readily turned with one pennyweight, when loaded with fifty-five pounds, but distinctly turned with four grains, when tried more patiently. This is about $\frac{1}{96000}$ part of the weight. In the same volume, a balance, by Mr. Whitehurst, is described, which weighed one pennyweight, and turned with $\frac{1}{2000}$ of a grain, or $\frac{1}{49000}$ of its weight. Ramsden's balance, turning on points instead of edges, is described in the seventy-fifth volume of the *Philosophical Transactions.* With a load of four or five ounces, a difference of one division in the index was made by $\frac{1}{160}$ of a grain. This is $\frac{1}{384000}$ of the weight, and, consequently, this beam will ascertain the weight correctly to five decimal places. The Royal Society's balance, which was recently constructed by Ramsden, turns on steel edges upon planes of polished crystal. Dr. Ure states, "I was assured that it ascertained a weight to the seven millionth part. I was not present at this trial, which must have required great care and patience, as the point of suspension could not have moved over much more than the two hundredth of an inch in the first half minute; but from some trial, which I saw, I think it probable that it may be used in general practice, to determine weights to five places and better. The assay balance is of a similar kind to that which is here described in detail, but small, and extremely delicate. It is used in docimastical operations, to determine exactly the weight of minute bodies. The beam should be made of the best steel, and of the hardest kind, as this metal is less apt to be spoiled with rust than iron, and it more easily takes a perfect polish, which, at the same time, prevents the rust. The longer the beam is, of course, the more exactly may the weight be determined; but, in general, ten or twelve inches is considered a sufficient length. The thickness of it should be so small, that two drachms might hardly be hung at either end without its bending; for the largest weight put upon it seldom exceeds one drachm. The whole surface of the beam should be without ornament, as these only collect dust, and render the balance inaccurate. The whole apparatus is, when used for nice experiments, enclosed in a case with glass faces, and which are opened only so far as may be necessary to introduce the weights and the body to be weighed.

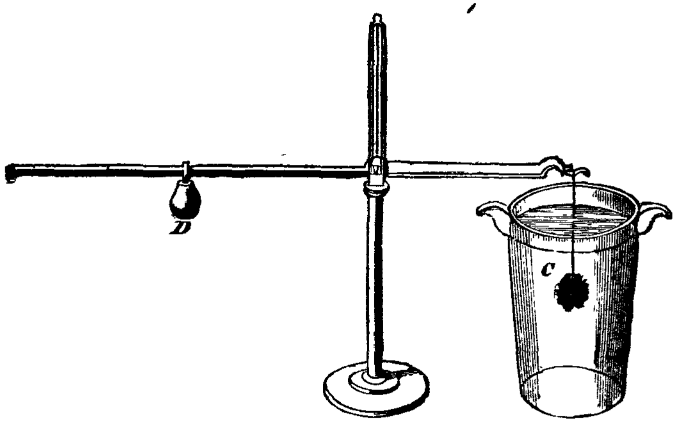
Balance Hydrostatic, is a balance furnished with apparatus adapted to ascertain the specific gravity of bodies, by weighing them in liquids, as well as in air. A common balance, of a good construction, and furnished with a small hook beneath one of the pans, is, with the usual appendages, quite sufficient for a hydrostatic balance. An accurate and delicate balance, that may be adapted to this purpose, and is easily constructed, is thus described in *Brewster's Philosophical Journal.* Let a slender beam of wood be procured, about eighteen, or twenty-four inches long, and tapering a little from the middle to each end. Let a fulcrum of tempered steel, resembling the blade of a penknife, be made to pass through the middle of the beam a little above the centre of gravity. Similar steel blades are also made to pass through the ends of the beam for suspending the scales. The fulcrum rests on two small portions of thermometer tubes, fixed horizontally on the upright support *e f*. The support



has a slit along the middle, to allow the needle at *e f* to play freely between the sides. A small scale, made of card, and divided into any number of parts, is

placed at *f* for the purpose of ascertaining the point at which the needle remains stationary. This balance possesses extreme delicacy. It may even be made more sensible than that belonging to the Royal Society of London. I have said nothing of the perfect equality of the two ends, as this condition is not at all necessary to the accuracy of the balance, according to the method of double weighing. To ascertain the weight of any body, place it in one of the scales, and bring the needle to any point by means of small shot placed in the other scale; observe the point opposite to which the needle rests, or the middle, between its extreme points of oscillation; remove the body, and put into the same scale as many known weights as will bring the needle to the same division as before. These weights will, evidently, be equal to the weight of the body, whether the arms of the balance be equal or not. This method of weighing is due to Bordá. The steelyard is sometimes employed to ascertain specific gravities, as in the balances of Lukin and Coates.

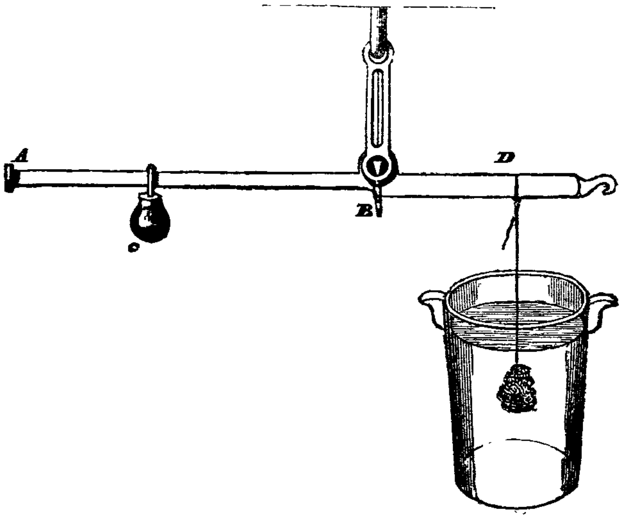
Lukin's Hydrostatic Balance is extremely simple, and is considered to be a very accurate instrument. The appearance is given in the accompanying figure. When unloaded, the arms are equipollent. C the body, whose specific



gravity is to be found, is suspended to the shorter arm of the instrument. On the longer arm, the movable weight D indicates the weight of the substance in air or water. If great accuracy is required, a second weight, which is a submultiple of the first, may be added on the longer arm. Then the division marked by the larger weight may be units, and that of the smaller, tenths, or hundredths, as may be thought proper.

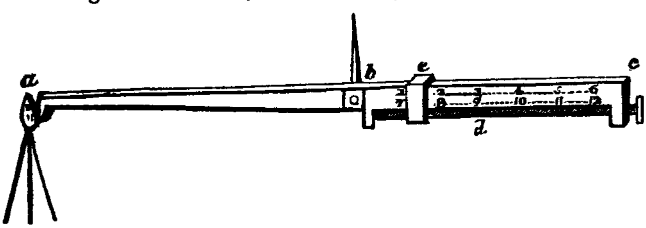
Coates's Hydrostatic Balance is upon the same principle as Lukin's, but differs in the mode of graduation. This being adapted for finding the specific gravity of minerals, instead of pointing out the actual and relative weights, it shows at once their specific gravity. The instrument is accurately balanced when unloaded, by making the shorter arm much larger than the longer one; and the latter is graduated, and marked with numbers, which every where show the quotient of the entire length of the longer arm, divided by the distance of the given mark from the end. Thus, at half the length, is marked the number 2; at one-third, the number 3; and so on. These numbers extend on the scale to rather more than 20, in order to render the instrument applicable to the heavier metals. In using this instrument, a weight is suspended by a hook at A, and the body under examination is to be hung by a horse hair on the shorter arm, and slid along as on the steelyard, till an equipoise is obtained, say at D. Then without altering its situation on the beam, the body is to be immersed in water, and balanced a second time, by sliding the weight C along the graduated arm, till the two are again in equilibrio. The hook of the weight will then at once indicate, by its situation on the scale, the actual specific gravity of the body, water being considered as unity. The instrument being supposed in equilibrio,

and the distance B D and the weight of the counterpoise being constant, the weight of the body varies as the distance of the counterpoise from B. Thus, if the counterpoise have to be removed $\frac{1}{4}$ nearer to the centre B, to balance the body when weighed in water, the specific gravity, as seen on the scale, will be



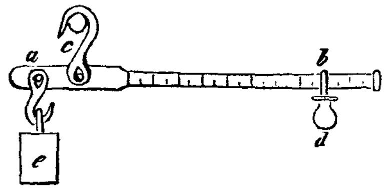
4, or four times greater than that of water. If it have to be removed $\frac{1}{12}$ nearer, the specific gravity is 12, and so on. The truth of the principle will appear, if we consider that the specific gravity of any body, as compared with water, is found by dividing its weight in air by its loss of weight in water. Now its loss of weight in water is proportional to the approximation of the weight C towards the centre. If, therefore, the whole arm, which always represents the weight in air, be divided by the quantity by which the weight approximates to the centre, it is clear that the quotient which is marked on the scale will be the true specific gravity required.

The annexed figure represents a balance beam, invented by Mr. J. H. Patten, Rhode Island, United States, for the purpose of taking the specific gravities of different bodies, and for the accurate weighing of minute quantities. The manner of using the instrument, it will be seen, is similar to that of Lukin's

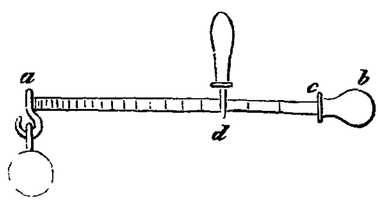


balance, just described. The beam *a b c* is made of steel sufficiently strong, but light. The dish is suspended at *a*; the beam itself upon an axis at *b*; at *c* is the milled head of a long screw, which is fitted with a shoulder and axis, and goes through the slide *e* that traverses upon *b c*, and carries the weight *d*. Now, suppose it required to obtain ten grains, place that weight in the dish *f*, and screw back the weight *d* until it exactly counterbalances it. If the weight be now removed, and a quantity of the substance to be weighed be substituted, until the index points to where it did at first, there will then be very nearly the

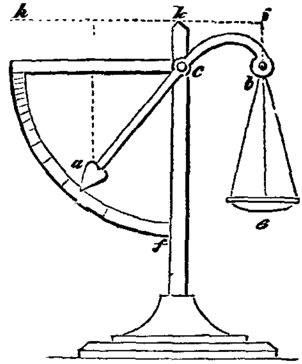
exact weight, differing only by the amount of the friction of the instrument. This beam may be used as a steelyard, by screwing the weight *d* to any number marked upon the scale; and should a greater quantity be required than that marked in the first line, another weight, double that of *d*, may be substituted. The ancient balance was the statera, or steelyard, in which the arms are of unequal length, and one movable weight is used, placed at different distances from the centre of motion, or fulcrum. The annexed figure represents the common steelyard, in which *c* is the fulcrum, or centre; *c b* the longer arm, and *c a* the shorter. *e* is the article to be weighed, suspended to the shorter arm, and *d* the constant weight. Now, if the shorter arm, by its additional thickness, be a counterpoise to the longer, so that the beam, when unloaded, may hang in a horizontal position, it is manifest, that equal weights, hung at equal distances from the centre, will balance each other; but if one of the weights be removed further from the centre, that side will preponderate. From this, it appears that a large weight *e* suspended at *b*, may be counterpoised by a small one suspended at *d*. If the distance between *c* and *d* be nine times greater than that between *c* and *e*, a weight of 10 lbs. at *d* will counterbalance one of 90 lbs. at *e*. To prevent the necessity for calculation, the longer arm is graduated, so that the exact weight may be known by inspection.



The Danish Balance is also a steelyard, but in this the weight is fixed at one end, the article to be weighed at the other, and the fulcrum, or support, movable between them. In the annexed cut, *b* represents the standard weight, and *a* the hook, to which the article whose weight is required, may be suspended, and *d* is the movable fulcrum. If *a b* were supposed a perfectly straight rod without weight, the gradations on it should be at equal distances; but as this cannot be the case in practice, a different arrangement is required. If *c* be the centre of gravity of the beam, and the fulcrum be placed at this point, it is clear that the beam will be supported in an horizontal position; but if a weight be appended to the hook *a*, the centre of gravity, which in all cases must be supported, will be removed to *d*, for example, and, consequently, the fulcrum must be moved to the same point. In this case, there is not only a difference in the leverage, or length of the arms, but there is the weight of the portion *c d* taken from one side and added to the other. The best method of graduating this instrument is by experiment,—by applying known quantities at the point *a*, and marking the place of the fulcrum *d* when an equilibrium takes place.

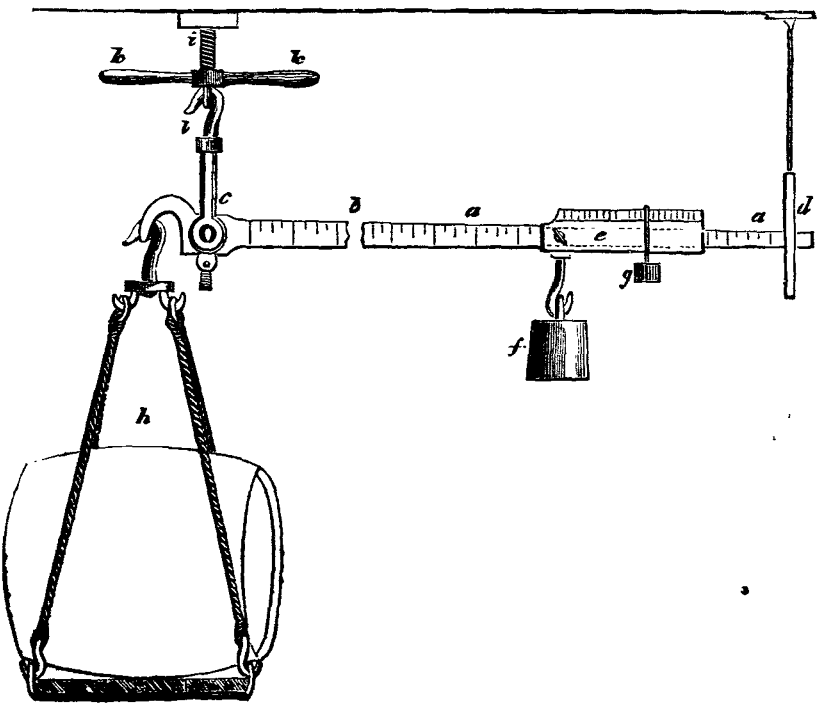


The Chinese Balance is a steelyard, somewhat different from the Roman statera. It is much used by the Eastern merchants in weighing gems and precious metals. The beam is a small rod of wood or ivory, about a foot in length. Upon this there are three lines of measure, made of delicate silver studded work. The scales commence at the end of the beam, whence the first extends to 8 inches; the second to $6\frac{1}{2}$; and the third to $8\frac{1}{2}$. The first indicates European weight, and the other two Chinese. At the other end of the beam a scale is suspended; and at three several distances from this end are fastened so many fine strings, forming so many different points of suspension. The distance of the first point from the end is $\frac{8}{5}$ of an inch; the second $\frac{16}{5}$; and the third $\frac{24}{5}$. When the instrument is used, it is hung up by one of the strings, and a sealed weight of about $1\frac{1}{4}$ oz. is hung upon some one of the divisions of the rule, so as to counterbalance the weight of the article, which is indicated by the graduations of the scale.



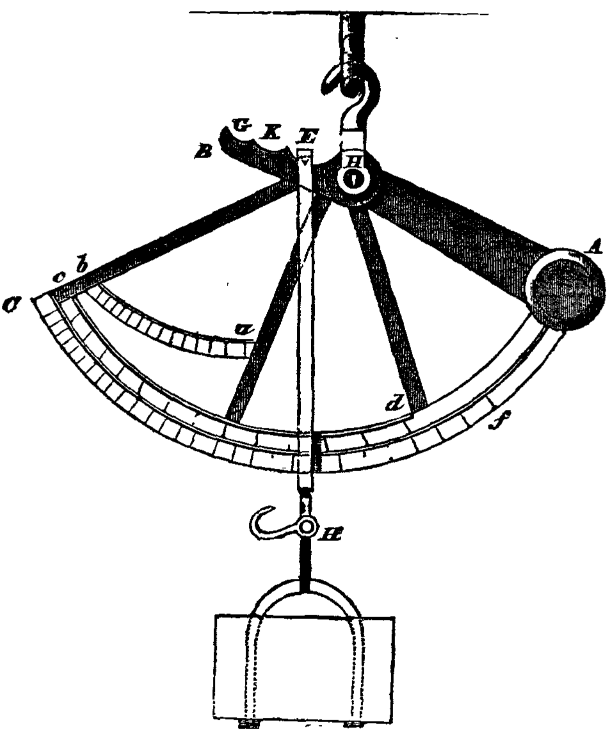
The Bent Lever Balance is represented in the annexed figure, in which *a c b* is a bent lever, moving on the centre *c* as its fulcrum, or axis, of motion. To the shorter arm of the lever at *b*, a scale-pan *e* is appended, while the other arm has a heavy weight affixed to its other extremity *a*, which passes over the quadrantal arch *f g*. The substance to be weighed being placed in the scale *e*, the end *a* will indicate the weight by the height to which it rises on the graduated arch. A little attention to the diagram will show that, as the end *b* descends, the other extremity *a* ascends, and, at the same time, removes to a greater distance, from a vertical line passing through the centre of motion. In the present position of the balance, the effective length of the arm *c b*, is *k i*, and of the arm *c a*, is *k d*. Now, as these are of equal lengths, the weight *a* (omitting the weight of the lever itself) will be equal to that of the substance placed in the scale. But as the weight approaches the point *g*, the effective length of *a c* will be represented by *k h*, and the weight *a* will therefore act with as much more power, as the length of *k h* exceeds that of *k d*. If the point continued at the same distance from the vertical line, passing through *c*, the efficacy of the weight would, at any point in the arch, be proportional to the length of a perpendicular drawn from that point to the vertical line; but as the distance of *b* is constantly varying, we can only state, generally, that the divisions will be nearer together as we approach the upper part of the scale.

Payne's Weighing Machine is of the steelyard kind; the longer arm is divided



by lines denoting the various weights, as usual; but, instead of the weights being suspended by hooks immediately on the beam, they are attached to a long case, or box, which slides with some friction along the beam. Beneath one end of this sliding box is a large hook, to which is suspended the heavy weight, which is used to measure the larger quantities, as hundred weights, and quarters, which are denoted by the divided lines on the beam, as the sliding box is drawn over it. To measure the smaller quantities, as pounds and ounces, there is a light scale of parts fixed to the top of the sliding box, to which a hook and weight are hung, which are applied in the same manner as the common steelyard. In the preceding engraving we have given a view of the whole arrangement, the longer arm of the beam being somewhat shortened to save room. In this representation, *a a* is the beam; *c* is the fulcrum; *d* a long rectangular loop through which the arm *a a* passes, and which serves to support it when not in use, or to limit its vibrations when employed in weighing; *e* is the sliding-box, with its graduated scale, for the minuter quantities, which are to be ascertained by the smaller weight *g*; *f* the larger weight, which may be secured at pleasure, at any point, by means of a thumb-screw above, half a turn of which fixes the slide against the beam, while the more minute quantities are being taken. The goods are placed in the scale *h*, which may then be raised from the ground by turning the handles *k k*, which causes the screw *i* to enter the nut above. Machines on this principle are made of all sizes, to weigh either tons or ounces.

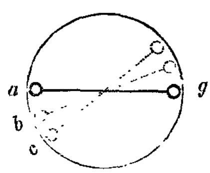
Braby's Balance, or *Weighing Apparatus*, unites the properties of the bent lever balance, and the steelyard. It has been termed a domestic balance by the



inventor, from its being peculiarly adapted for family purposes, such as weighing meat, bread, butter, &c. In the figure A B C is a frame of cast-iron, which has the greater part of its weight towards A, in consequence of its

greater thickness at that part. F is a fixed fulcrum, and E H a movable suspender, which has a scale and hook at its lower extremity. E K G are three distinct points to which the suspender E H may be applied, and to which belong, respectively, the three graduated scales of weights *f* C, *c d*, *a b*. When the suspender is applied at G, the apparatus is in equilibrio with the edge A B horizontal, and the suspender cuts the zero of the scale *a b*. If a weight be now placed in the scale, the whole apparatus turns about F, and the point on the side B C descends till the equilibrium is again established. The weight placed in the scale may now be read off from the point where the suspender cuts the scale *a b*, which registers to ounces, and is adapted to bodies whose weight does not exceed two pounds. If the weight of the body exceeds two pounds, but is under eleven, the suspender is placed at K; and when the upper edge of the balance is horizontal, the weight, or number 2, is found a little to the right of the index of the suspender; if, now, weights exceeding two pounds be placed in the scale, the whole again turns about F, and the weight of the body is shown on the graduated arc *c d*, which extends to eleven pounds, and registers to every two ounces. If the weight of the body exceeds eleven pounds, the suspender is hung on at E, and the weights are ascertained in the same manner on the scale *f* C to thirty pounds; the subdivisions on this scale are quarters of pounds. The same principle might be extended to weights greater than the above. To prevent mistake, the three points of support, G, K, E, are numbered 1, 2, 3; and the corresponding arcs are respectively numbered in the same manner. When the hook is used instead of the scale, the latter is turned upwards, there being a joint at H for that purpose.

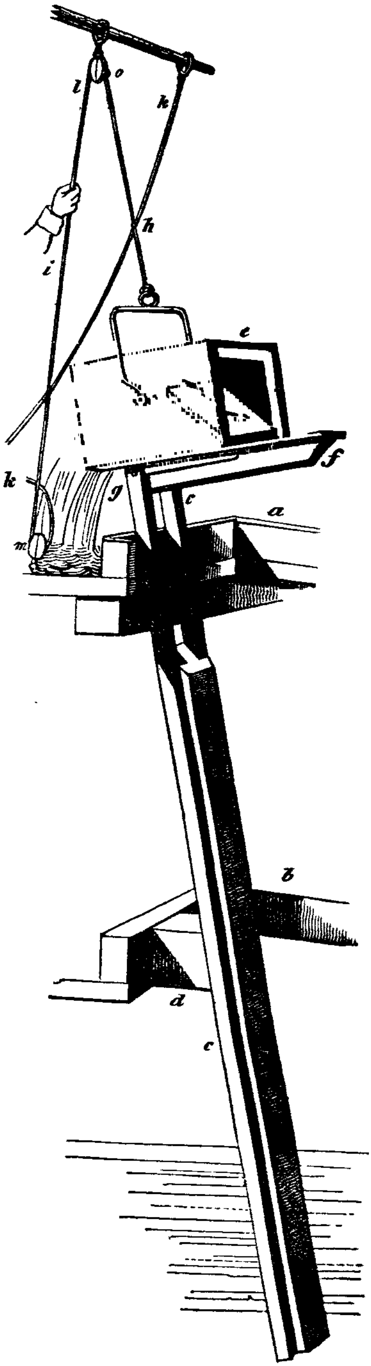
Balance of Torsion. If a piece of very fine wire, silk, or spun glass, extended by a weight, be suspended to any fixed point, and then twisted, it will, when released, begin to untwist itself, and, by its momentum acquired in the act of untwisting, will twist in the opposite direction. It will afterwards return, and thus, by a series of oscillations, continually diminishing in amplitude, it will at length come to a state of rest in its original position. Now, if a needle, or an index similar to the hand of a watch, be attached to the lower extremity of the suspended wire, and a circle, having its circumference graduated into degrees, or other equal divisions beneath it, it will form the balance of torsion. To measure small forces, as those of electricity, magnetism, &c., with this balance, they are made to act on one extremity of the index; and when the force is in equilibrio with the tendency of the wire to untwist, the angle which the index makes with its quiescent position, which is called the angle of torsion, is the measure of the force employed. In the annexed cut, let *a b c g* represent the graduated circle, and *a g* the index suspended by the silver wire at the point *e*. Suppose any force act upon *a* so as to move it to *b*, then will the arcs *a b* represent the angle of torsion. Suppose another force to act at the same distance, and move the ball to *c*, then will the latter force be measured by the arc *a c;* and hence the intensity of the former force is to that of the latter, as *a b* to *a c*. To



preserve the index from disturbance by the air, the whole is enclosed in a glass cylinder, at the upper part of which, where the wire is attached, there is an index and a divided circle, which is used to twist the wire, when the measure of a force becomes greater than a whole circumference. The sensibility of this instrument will depend on the dimensions of the suspending wire. Thus, if the *length* of the wire be doubled, the sensibility will be increased in the same proportion, *i. e.* only half the force will be required to twist the wire a given number of degrees. If the *diameter* of the wire be increased, the sensibility is diminished in a great degree; thus, if there be two wires of the same length, but one twice the thickness of the other, the latter will require sixteen times more power than the former to twist it through a given number of degrees; the force of torsion being proportional to the fourth power of the diameter, and sixteen it will be seen is the fourth power of two. If the wire be increased three times in diameter, the sensibility will be decreased $3 \times 3 \times 3 \times 3$ 81 times.

Balance of a watch, is that part which, by its motion, regulates and determines the vibrations. The circular part is called the rim, and its spindle the verge; there also belong to it two pallets, that play in the fangs of the crown-wheel. In pocket watches, the strong stud in which the lower pivot of the verge plays, and in the middle of which one pivot of the crown-wheel runs, is called the potence; the wrought piece, which covers the balance, and in which the upper pivot of the balance plays, is the cock; and the small spring in the new pocket-watches, is called the regulator. The motion of a balance, like that of a pendulum, being reciprocating, while the pressure of the wheels is in one direction, it is obvious that some contrivance must be used to accommodate one to the other. When a tooth of the wheel has given the balance a motion in one direction, it must quit it, that it may obey an impulsion in the opposite direction. The balance, or pendulum, thus escaping from the tooth of the wheel, or the tooth escaping from the balance, has given to the general construction the name of scapement. See HOROLOGY.

BALING MACHINE. A machine for raising water from the hold of ships. When, from the pumps being rendered useless by an accident, or from the extent of a leak, the water gains upon the pumps, the method usually resorted to for getting rid of it, is to bale it out at the several hatchways, by means of canvas buckets; but from the difficulty of filling and raising the buckets, from the heavy rolling of the vessel, the most painful and long continued exertions prove insufficient to save a ship from foundering. An apparatus, of great simplicity of construction, and facility of application, for the purpose of baling, has been invented by Mr. J. Dennett, of the Isle of Wight, which will, no doubt, be found a powerful auxiliary to a ship's pumps in cases of danger. The annexed figure is a perspective view of this machine. *a* and *b* are part of the hatchways of the upper and lower



decks; *c c* is a long rebated slide, in an inclined position, reaching from a little above the coamings of the upper deck, to the ballast in the hold; *e* is a square bucket, made to slide on the rebate *c c;* its bottom is a flap valve, so that when it slides down into the water, it opens, and the bucket fills instantly, and closes, upon being drawn up full of water, without any attention on the part of the workmen. The upper portion *f* of the rebate of the long slide is made detached, and is fixed in its place by the pin *g*, on which it turns as on an axis. The bucket is shown discharging the water on the upper deck; and when the rope *h i k* is let go, the bucket falls down, rights itself, and the upper portion *f* of the slide falling with it, and joining the lower part, the bucket runs down the whole of the slide into the water, is instantly filled, and drawn up again by pulling the parts *i k* of the rope, the part *k* passing through a leading block *m* on the deck. A pin is fixed on the top of the rebate, so that when the bucket rises up, and is only in the loose portion *f*, it is stopped by the pin; and the loose portion *f*, by farther pulling, rises out of its place, and upsets the bucket. To prevent the bucket being raised higher than is necessary to discharge the water, a knot is worked in the rope, which forms a stop against the block *l*. The block *l* is made fast to a yard-arm, and the upper end of the rope *k* is secured to the same, or elsewhere, with just length enough to let the bucket reach the bottom of the slide.

BALLAST. Heavy substances placed in the lowest part of the hold of a ship, to preserve the vessel in an upright position, when under sail. It consists generally either of masses of cast-iron 3 feet long and 6 inches square or of small round stones, which is called shingle ballast.

BALLAST LIGHTER. A vessel employed to remove sand, silt, or other depositions from the beds of rivers, harbours, docks, &c. which is effected as follows: The vessel, which is a species of open barge, being moored, a leather bag, the mouth of which is distended by an iron hoop, fastened to a pole of sufficient depth to reach the bottom, is put over the side, and descends to the bottom in an inclined position: two or three turns are taken with a rope round the pole, and a timber-head near the stern of the boat. A rope attached to the hoop of the bag, and passing over a small crow at the fore part of the vessel, is then brought to a winch, and the bag is gradually wound up by a man at the stern slowly slacking the rope which passes round the pole, thus allowing it to rise as it approaches the vertical position; at the same time causing such friction, that the edge of the hoop digs into the ground, and the leather bag receives whatever passes through the hoop. When the bag is raised above the side of the boat, it is swung into the boat by the crane, and its contents discharged into the bottom of the vessel.

BALLISTA. A machine used in ancient warfare for throwing stones or darts. It in some measure resembled the cross-bow, but possessed far greater projectile power. It has been thus described: An iron cylinder was fastened between two planks, from which proceeded a hollow square beam, placed crosswise, and fastened with cords, to which were added screws. At one end of this stood the engineer, who put a wooden shaft with a large head into the cavity of the beam; this done, two men bent the engine, by turning some wheels. When the top of the head was drawn as far as the cords would allow, the shaft was driven out of the ballista. The ballista depended and acted upon the same principles as the catapulta, the moving power of which depended on the elasticity of twisted cords, made with women's hair, that of horses, or the entrails of animals. The ballista was usually employed in throwing darts, though, like the catapulta, it sometimes was used in projecting large stones. It is recorded by Vegetius, that the ballista discharged darts with such velocity and force, that nothing could resist their power: and Athenæus adds, that Agistratus made one of little more than two feet long, which shot darts 500 paces.

BALLISTIC PENDULUM. An ingenious machine, invented by Mr. Benjamin Robins, for ascertaining the velocity of military projectiles, or the force of fired gunpowder. It consists of a large block of wood, fixed to the end of an iron rod, and suspended like the pendulum of a clock. When the pendulum is at rest, a gun is pointed towards the centre of the block, and a ball fired point blank into it In consequence of the magnitude of the block, compared with the ball

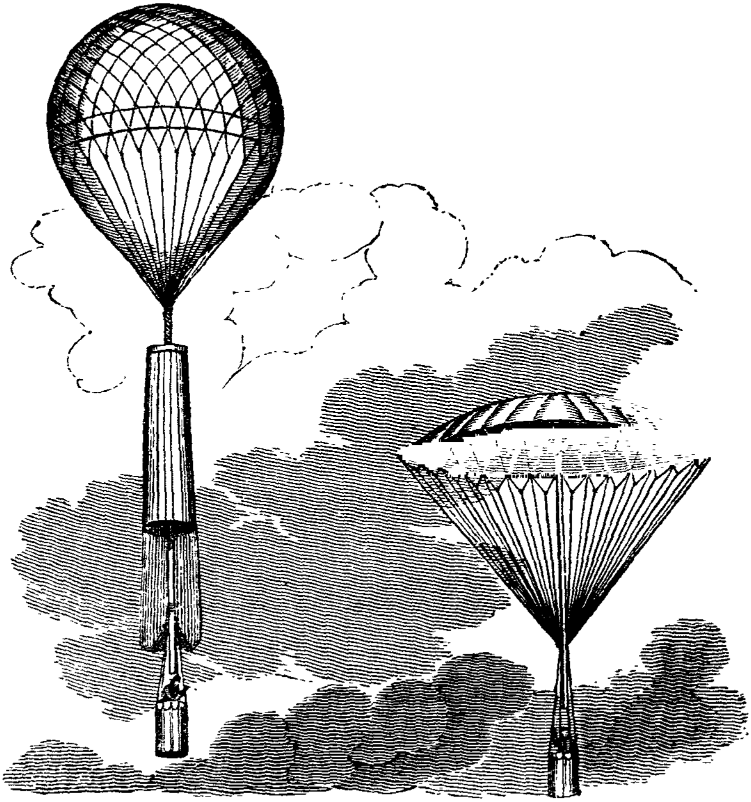
or bullet, a very small velocity is given to the former, which being accurately measnred, the velocity of the ball is easily deduced; for, as the weight of the ball is to the sum of the weights of the ball and block, so is the observed velocity of the block to a fourth quantity, which is the velocity of the ball sought. A variety of experiments have been made by Dr. Hutton with this pendulum, from which a number of useful rules have been deduced relative to the velocity produced with different charges of powder, with guns of different lengths, and with different sized balls. A complete series of experiments was also instituted relative to the resistance of the air to different velocities, varying from 0 to 2,000 feet in a second. Among other results, he ascertained that inflamed gunpowder expands itself with a velocity of about 5,000 feet in a second.

BALLOON, in Chemistry, a glass vessel to receive the product of distillation.

BALLOON, Air. A bag made of silk, paper, or other light material, for containing heated air, or gas, of less specific gravity than the atmosphere. If the weight of the balloon, and of the heated air or gas which it contains, be less than that of an equal bulk of atmospheric air, the balloon will ascend in consequence of the equilibrium of atmospheric pressure being disturbed; the pressure of the column of which the balloon forms a part, being less than that of the ordinary atmosphere. The ascending, or upward pressure, therefore, carries the lighter body up until it arrives at a more attenuated medium, which is of the same specific gravity. After the discovery of hydrogen gas, the lightest of all ponderable substances, it occurred to Dr. Black, that a thin bag filled with this would ascend in the air. He suggested the employment of the allantois of a calf for this purpose, but Mr. Cavallo, who performed various experiments on this subject, found that this, and the lightest bladders he could procure, were all too heavy. Chinese paper was also tried, but the gas escaped rapidly through it. By filling soap-sud bubbles with hydrogen gas he succeeded, and these balloons rapidly ascended to the ceiling. Within these few years small experimental balloons have been formed of the crop of a turkey, which, when the fat, &c. have been separated, are sufficiently light to ascend if filled with hydrogen gas, although some of them do not contain more than a pint. At about the same period of time, two brothers, named Montgolfier, natives of Annonay, in France, were trying experiments with balloons filled with heated air, the specific gravity of which is less than that of air at the ordinary temperature. They were led to these experiments by observing the rapid ascent of smoke from chimneys, and imagined that if the smoke were confined in a large and light bag, it would be borne upwards. A bag of fine silk, in the shape of a parallelopiped, was constructed, and burning paper was held under the aperture, until the balloon contained a sufficient quantity of rarefied air to carry it up to the ceiling of the apartment. When this experiment was repeated in the open air, the vessel ascended to an altitude of about 70 feet. Other balloons on a larger scale were constructed, and a public exhibition of one containing 23,000 cubic feet was made at Annonay, on the 5th of June, 1783. This was formed of linen lined with paper, and when filled with heated air, was capable of raising 500 lbs. appended to the extremity. One of the Montgolfiers shortly after this visited Paris, and as the affair had excited much attention, he was invited by the Academy of Sciences to repeat the experiment at the expense of the Society. A large balloon, of elliptic shape, was filled with heated air, in the presence of the members, and in this state it would have ascended with a weight of 500 lbs. if the cords which prevented it had been liberated. As it was intended to exhibit the ascent before the king of France and his court, this was not done, and the balloon was subsequently so much damaged by wind and rain, that it became necessary to construct another. This was nearly 60 feet in height, and 43 in diameter, and a wicker cage was attached to it, containing a sheep, a cock, and a duck. The balloon, when duly prepared, ascended with these to an altitude of about 1,400 feet, and would have ascended to a greater height had not a violent gust of wind torn the cloth, and permitted the heated air to escape. The facility of ascending in the atmosphere being thus fully established, Pilatre de Rozier offered personally to ascend in another balloon, to be constructed by Montgolfier. Accordingly another balloon was completed, of enormous mag-

nitude. The height was 74 feet, and the diameter 48; and its weight, including the car and necessary fuel for continuing the fire, was 1600 lbs. By this the intrepid Pilatre de Rozier made several ascents to an altitude of from 200 to 330 feet, but in these preliminary attempts the balloon was confined by cords. Subsequently he ascended in company with the Marquis d'Arlandes, with the balloon unrestrained, and they continued in the air about 25 minutes, and descended at a distance of about five miles from the place of their departure. The difference between the specific gravity of air heated by the means employed, and that of air at ordinary temperatures, not being very considerable, the buoyant power of a balloon thus filled, was comparatively small, and therefore it was indispensable to employ a large quantity, and, consequently, a large machine to contain it. To double the volume of air by heat, requires a temperature of nearly 480° Fahr. Messrs. Charles and Roberts therefore tried the experiment of filling a silk bag only 13 feet in diameter, with hydrogen gas, which is only $\frac{1}{15}$ the weight of ordinary air. The experiment was perfectly successful. This small balloon was capable of raising 35 lbs., and on being liberated, it ascended to a considerable height, and after remaining three-quarters of an hour in the air, descended at a distance of fifteen miles from the spot where it had ascended. A balloon formed of silk, and varnished with a solution of Indian rubber, was then constructed, which was filled with hydrogen gas. The diameter was $27\frac{1}{2}$ feet, and it was covered with a net-work, to which a car, capable of holding two persons, was attached. Messrs. Charles and Roberts ascended from Paris in this, in December 1783, and after remaining in the air an hour and three quarters, they alighted at a distance of 27 miles without accident. A sufficient quantity of gas still remained in the balloon to carry up one person, and Mr. Charles again ascended alone, and attained an altitude of more than 10,000 feet. Shortly after this successful effort, attempts were made to guide or impel a balloon in any required direction; and if this could have been accomplished, the invention would have introduced a new era in science. Mr. Blanchard applied a species of wings to the car, but was unsuccessful in his attempt to travel against the direction of the wind; nor was Morveau more fortunate with large oars or sails, introduced with the same design. Numerous contrivances have been since adopted, but all have been ineffectual in practice; and, indeed, when the great extent of surface which a balloon presents to the impulsive force of air in motion is duly considered, the probability of overcoming that force by any means which can be commanded by the aerial voyager, seems very remote. Endeavours have also been made to economize the gas which the balloon contains. A much larger quantity than is necessary to create the buoyant power required to carry up the voyagers, is introduced, and to occasion the descent of the machine, the gas is permitted to escape by a valve; but if the aeronaut require again to ascend in consequence of the unfavourable nature of the ground on which he is likely to descend, or from any other cause, he must part with ballast, which may be essential to his safety. The Duke de Chartres, accompanied by Charles and Roberts, ascended in a balloon filled with hydrogen gas, which contained a smaller within it, to be filled with common air, by means of a pair of bellows, as occasion might require. By inserting common air into the small balloon, the specific gravity of the machine would be increased, and it would descend without loss of gas, and reascend by withdrawing the common air. However ingenious the contrivance, it was not found successful in practice, chiefly, perhaps, on account of the unfavourable state of the wind, which was tempestuous when the experiment was made. Pilatre de Rozier and Mr. Romaine, with the same design introduced a balloon filled with heated air below the ordinary balloon containing hydrogen gas. The buoyant power of the heated-air balloon was equal to about 60 lbs.; and by removing the source of heat, the specific gravity of the whole machine was increased, so that it was not necessary to part with any gas during a voyage. The attempt to carry this plan into execution was fatal to both voyagers. The upper balloon, by means unknown, took fire, and the intrepid De Rozier and his companion were precipitated to the earth and killed. It is not our purpose to describe the various attempts that have been subsequently made to

improve the construction of balloons, or to render them subservient to scientific purposes, since little has been effected towards accomplishing these objects. We cannot, however, omit a description of an addition to the balloon, called a parachute, which was first employed, with daring courage, by M. Garnerin. The balloon was of the usual form, made of oiled silk, and filled with inflammable gas; it was covered, as represented in the annexed engraving, with a netting, from which cords proceeded that were tied together at a few feet below the balloon; the several cords thus collected were then twisted so as to form a



single rope, which was passed through the parachute, and fastened to the car, or basket. The real structure of the parachute is best seen in its expanded state, as shown in the descent, forming a near resemblance to a large umbrella; it was made of canvass, and about thirty feet in diameter; it had no ribs, the figure of its dome being preserved by the surrounding cords. The length of these cords, or ropes, from the edges of the dome of the parachute, to where they are connected together, was about 30 feet; and from this point of connexion, other shorter ropes proceeded, which were attached to the edges of the circular basket in which the aeronaut was situated. In the place of the handle of a common umbrella, a long tin tube was fixed in the parachute, through which the single rope before-mentioned was passed, to prevent its becoming entangled, and to allow it to slip away with certainty when severed for the purpose of descending. The ascent took place on the 21st of September, 1802, from St. George's Parade, North Audley-street. The balloon began to be filled about two o'clock; 33 casks filled with diluted sulphuric acid, together with a quantity of iron filings, were

employed for the production of the hydrogen gas. These communicated with three other casks, or general receivers, to each of which was affixed a tube that emptied itself into the main tube connected to the balloon. At six o'clock the balloon was completely filled; when it rose with its long appendage of the parachute, the aeronaut in the little basket closing the train. Thousands of acclamations rent the air, while the eyes of tens of thousands of spectators were fixed in astonishment and admiration at the gallant adventurer; feelings which could be only surpassed by the most intense and painful anxiety for his safety. The weather was beautifully fine, with scarcely any wind. For eight minutes this intrepid man continued to ascend, till he arrived at such an immense height as to be scarcely visible, when he cut away the balloon. The parachute did not expand immediately, and he fell with great velocity for a short space of time; when it opened

gas as the balloon requires, amounts to nearly a hundred pounds. The latter product of the distillation of coal, when the more valuable illuminating gas is evolved, answers the purpose best, as it contains much less carbon, and is, consequently, considerably lighter. The best material for constructing a balloon, is the silk stuff called lustring. When cut into gores it should be stretched by weights, or other means, and kept in this state several hours before it is varnished or sewn. It is usual to apply boiled linseed oil, containing a small quantity of oxide of lead, for the first coat of varnish, and a solution of caoutchouc (Indian rubber) in oil of turpentine, for the last. The seams should be doubly sewn and overlapped; and, when finished, a hot smoothing-iron should be passed over them, the silk being protected by an intervening sheet of paper. The gores should be cut with great precision. A net-work of strong hempen twine should be accurately fitted to the balloon, the meshes at the upper extremity being smaller than those below. To the separate cords which terminate the net-work, a circular hoop is attached, from which the car is suspended by strong ropes. The whole of the net-work and ropes should be so adjusted, that the strain, or pressure, is equalized over the whole surface of the balloon. The valve for permitting the escape of gas must be retained in its place by a sufficient spring; and to render it perfectly air-tight, a luting of wax and oil is generally employed around the edges. The cord by which the valve is opened passes through the interior of the balloon; and great care is necessary to prevent it being entangled. The extremity of this cord should never be fastened to the car, as in the event of its oscillation, the valve might be opened, and retained in that state until the greater part of the gas escaped. A grappling-iron, attached to a strong rope, is an indispensable appendage to a balloon. As much ballast as can be taken should always be employed. It frequently occurs that the aerial voyager is far above the clouds, and loses sight entirely of the earth by their intervention; on passing through them, he may find that the spot on which he is descending is unfavourable. A few pounds of ballast thrown out, will occasion the balloon again to ascend, and pass over the inappropriate landing-place. The writer of this article was thus situated; and all the ballast being discharged, he was in imminent danger of descending in an arm of the sea. A contrary current, near the surface of the earth, however, gave the balloon another direction, when escape seemed almost impossible. The appearance of the scenery below to an aeronaut is inexpressibly beautiful; but as a bird's-eye view only can be taken, no correct opinion can be formed of the altitude of buildings, hills, or trees. On this account, much of the grandeur of an extensive prospect is lost. The chief inconvenience experienced is from the sudden variations of temperature. The upper regions of the atmosphere are intensely cold when the sky is cloudless, even although the sun be shining in meridian splendour. In an ascent made in August, when the thermometer was 74° in the sun at the time of ascent, the writer observed, in less than twenty minutes, that the mercury indicated a temperature of 31°.

BALLUSTRADE. A series, or row, of ballusters, joined by a rail, serving both as a rest, and as a fence or enclosure, to stair-cases, balconies, &c.

BALSAMS are vegetable juices, either liquid, or which spontaneously become concrete, consisting of a substance of a resinous nature, combined with benzoic acid, or which are capable of affording benzoic acid, by being heated alone, or with water. They are insoluble in water, but readily dissolve in alcohol and ether. The liquid balsams are copaiva, opo-balsam, Peru, styrex, and tolu; the concrete are benzoin, dragon's blood, and storax.

BALSAM OF SULPHUR. A solution of sulphur in oil.

BALDWIN'S PHOSPHORUS. Ignited nitrate of lime.

BAMBOO is a native of the hottest regions of Asia. It is likewise to be found in America, but not in that abundance with which it flourishes in the old world. It is never brought into this country in sufficient supply, though it is admirably adapted for many purposes. In the countries of its production, it is one of the most universally useful plants, and of the most rapid growth, rising from fifty to eighty feet the first year, and the second, perfecting its timber in hardness and elasticity. It grows in stools, which are cut every two years. Its young

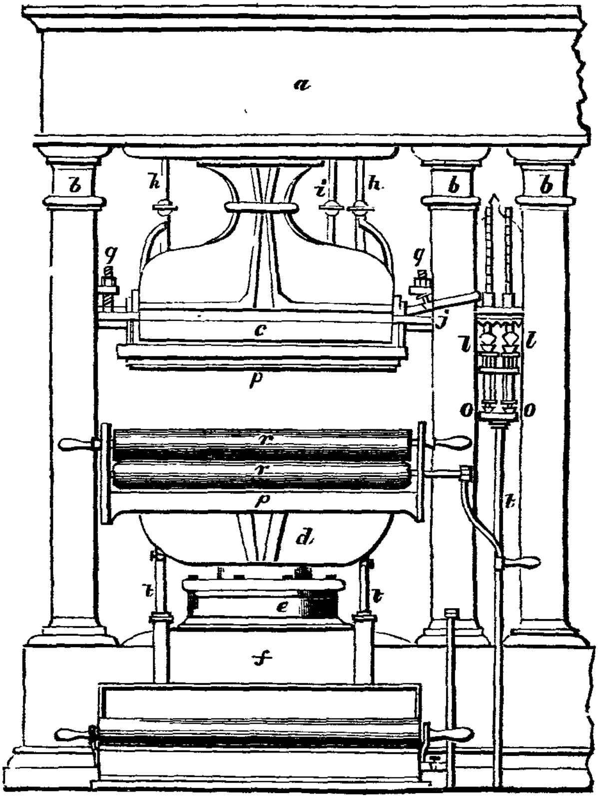
shoots and roots make an Indian pickle; its light, graceful, knotted stalk, is used in many articles of furniture for the rich; and its timber forms almost entire houses for the lower orders. The quantity of timber furnished by an acre of bamboo is immense. Bridges, boats, masts, rigging, agriculture, and other implements and machinery; carts, baskets, troughs, pipes for conveying water, pumps, fences for gardens and fields; tables, chairs, bedsteads, bedding, barrows, fences, sacking, cordage, oakum, candle-wicks, whips, &c. are made of it. Macerated in water it forms paper; the leaves are generally put round the tea sent to Europe; the thick inspissated juice is a favourite medicine. It is said to be indestructible by fire, to resist acids, and, by fusion with alkali, to form a transparent glass. In Malabar, the bamboos are trained over iron arches, and when they have assumed the curve of the mould, are used for roofs to palanquins, and sell at five or six hundred rupees a set.

BAMBOO HABIT. A Chinese contrivance, by which a person who cannot swim, may easily keep himself above water. Four pieces of bamboo, about a man's length, placed horizontally, and at right angles, in parallel pairs, and tied firmly at the four corners, the opening being just sufficient to admit the head and shoulders to get through, is then tied securely to the body of the person using it.

BANDANNAS. A name given to a certain description of silk handkerchiefs manufactured in the East Indies, the patterns of which generally consist of square or circular spots, variously arranged upon a red, blue, or yellow ground. An imitation of these handkerchiefs upon cotton, produced by first dying fine calico of a brilliant Turkey red, and after discharging the colour from those parts which, in the pattern, are white, by means of liquid chlorine, now forms a considerable branch of the cotton manufacture of this country, and an important article for exportation. A correct account of this process will be found in the following description of the great bandanna gallery, in the Turkey red manufactory of Messrs. Monteith & Co. of Glasgow, who obtained a patent for the process. Their new arrangement of their hydrostatic presses in their discharging gallery, was completed in 1818, under the direction of Mr. G. Ridger, sen. manager of the works. It consists of sixteen of these engines, beautifully constructed, placed in subdivisions of four; the spaces between each set serving as passages to admit the workmen readily to the back of the press. Each subdivision occupies 25 feet; hence the total length of the whole apparatus is 100 feet. To each press is attached a pair of patterns in lead (or plates as they are called) in which all those parts of the design which are to be white are cut away, so as to form recesses in the plates. One of these plates is attached to the upper block of the press, which block turns on a kind of universal joint, so as to apply exactly to the under plate. The latter rest on the sill or movable part of the press; when this is forced up, the two patterns close on each other with the greatest nicety, by guide pins at the corners fitted with the utmost care. The power which impels this great hydrostatic range, is placed in a separate apartment, called the machinery room. This machinery consists of two cylinders of a peculiar construction, called the prime cylinder, having pistons very accurately fitted to them. To each of these cylinders three small force-pumps, worked by a steam engine, are connected. The piston of the larger cylinder is 8 inches in diameter, and is loaded on the top with a weight of 5 tons; it can rise through a space of 2 feet. The piston of the other cylinder is only 1 inch in diameter, and is, likewise, loaded with 5 tons, and can also rise through a space of 2 feet. The pistons being at their lowest point, water is injected by the force-pumps into the prime cylinders, until the loaded pistons have arrived at their highest points, in which state they are ready for working the hydrostatic discharge presses; the water-pressure being conveyed from one apartment to the other, through strong copper tubes of small calibre passing beneath the floor. Two valves are attached to each press, one opening a communication between the large prime cylinder and the press cylinder, and the other between the small prime cylinder and the press. The function of the first is simply to lift the under block of the press into contact with the upper block; that of the second, to give the requisite compression to the cloth. A third

valve is attached to the press for the purpose of discharging the water from its cylinder, when the press is to be relaxed in order to remove or draw through the cloth. From twelve to fourteen pieces of cloth previously dyed Turkey red, are stretched over each other as parallel as possible, by a particular machine. These parallel layers are then wound round a wooden cylinder, or drum, which is then placed at the back of the press. A portion of the fourteen layers of cloth, equal to the area of the plates, is next drawn through between them, by hooks attached to the two corners of the web. On opening the valve connected with the 8-inch prime cylinder, the water enters the press cylinder, and instantly lifts its lower block, so as to apply the under plate with the cloth close to the upper one. This valve is then shut, and the other is opened. The pressure of 5 tons in the 1-inch prime cylinder is now brought to bear on the piston of the press, which is 8 inches diameter. The effective force here, therefore, will be 5 tons × 8=320 tons, to compress the cloth between the plates. The next step is to admit the bleaching or discharging liquor (aqueous chlorine, obtained by adding sulphuric acid to the solution of chloride of lime) to the cloth. This liquor is contained in a large cistern in an adjoining house, from which it is run at pleasure into small lead cisterns attached to the presses; which cisterns have graduated index-tubes for regulating the quantity of liquor according to the discharge pattern. The stop-cocks on the pipes and cisterns containing this liquor, are all made of glass. From the measure cistern the liquor is allowed to flow on to the surface of the upper plate, and percolating through the portions of the cloth which lie under the open parts of the pattern, it extracts the Turkey red dye. The liquor is finally conveyed to the waste-pipe from a groove in the under block. As soon as chlorine liquor has passed through, water is admitted in a similar manner to wash away the remains of it; otherwise, on relaxing the pressure, the outline of the figure discharged would become ragged. The passage of the discharge liquor, as well as of the water, is occasionally aided by a pneumatic apparatus, or blowing machine, consisting of a large gasometer, from which air, subjected to a moderate pressure, is allowed to issue and act in the direction of the liquid in the folds. By an occasional twist of the air stop-cock, the workman can also ensure the equal distribution of the discharging liquor over the whole excavations in the upper plate. When the demand for goods is pressing, the air apparatus is much employed, as it enables the workman to double his product. The time requisite for completing the discharging process, in the first press, is sufficient to enable the other three workmen to put the remaining fifteen presses in operation. The *discharger* proceeds now from press to press, admits the liquor, the air, and the water; and is followed, at a proper interval, by the assistants, who relax the presses, move forwards another square of the cloths, and then restore the pressure. When the sixteenth press has been liquored, it is time to open the first press. In this routine, about ten minutes are employed; that is, 224 handkerchiefs (16 × 14) are discharged in ten minutes. The whole cloth is successively drawn forward to be treated in the above method. When the cloth escapes from the press, it is passed between two rollers in front, from which it falls into a trough of water placed below. It is finally carried off to the washing and bleaching department, where the lustre both of the white and the red is considerably heightened. By the above arrangement of presses, 1600 pieces of 12 yards each=19,200 yards are converted into bandannas in the space of ten hours, by the labour of four workmen. The following engraving exhibits an elevation of one of the presses. *a* is the top of the entablature; *b b b* cheeks of ditto, or pillars; *c* upper block for fastening the upper pattern to; *d* lower or movable block; *e* the cylinder; *f* the sole or base; *g* the water trough for the discharged cloth to fall into; *h h* tubes to admit the water; *i* tube for the air; *j* cock to admit the liquor from the meter; *k* cistern, or liquor-meter, having two glass tubes for indicating the quantity of liquor in the cistern; *l l* glass stop-cocks for admitting the liquor into the cistern; *o o* stop-cocks for admitting water; *p p* pattern plates; *q q* screws for setting the patterns parallel to each other; the snuffs are perforated with a ¼-inch drill; the lower frame has pins corresponding with these perforations, so that the patterns are guided into

exact correspondence with each other; *r r* rollers, which receive, and pull through, the discharged cloth, from which it falls into the water trough; *s* stop-cock for filling the trough with water; *t t t* waste tubes for water and liquor. The patterns, or plates, which are put into the presses to determine the white figures on the cloth, are made of lead, in the following way: A trellis frame of



cast iron, one inch thick, with turned-up edges, forming a trough rather larger than the intended lead pattern, is used as the ground work. Into this trough is put a lead plate, and firmly secured by screws passing from below. To the edges of this lead plate, the borders of the piece of sheet lead which covers the whole outer surface of the frame are soldered: thus a strong trough is formed, about one inch deep. The upright border gives strength to the lead plate, and serves to confine the liquor. A thin sheet of lead is now laid on the thick plate of lead, and is soldered to it round the edges. Both sheets must be made very smooth beforehand, by hammering them on a smooth stone table, and then finishing them with a plane. The surface of the thin sheet (now attached) is to be covered with drawing paper pasted down upon it, and upon this the pattern is to be drawn. It is now ready for the cutter, who, in the first place, fixes down with brass pins all the parts of the pattern which are to be left solid. He then proceeds with the little tools used generally by block cutters, which are fitted to the different curvatures of the pattern, and cuts perpendicularly quite through the thin sheet. The pieces thus detached are easily lifted out, and thus the channels are formed which design the white figures on the red cloth. At the bottom of the channels a sufficient number of small perforations are made through the thicker sheet of lead, so that the discharging

liquor may have free ingress and egress. Thus one plate is finished, from which an impression is to be taken, by means of printers' ink, on the paper pasted on another plate; the impression is taken in the hydrostatic press. Each pair of plates constitutes a set, which may be put into the presses, and removed at pleasure.

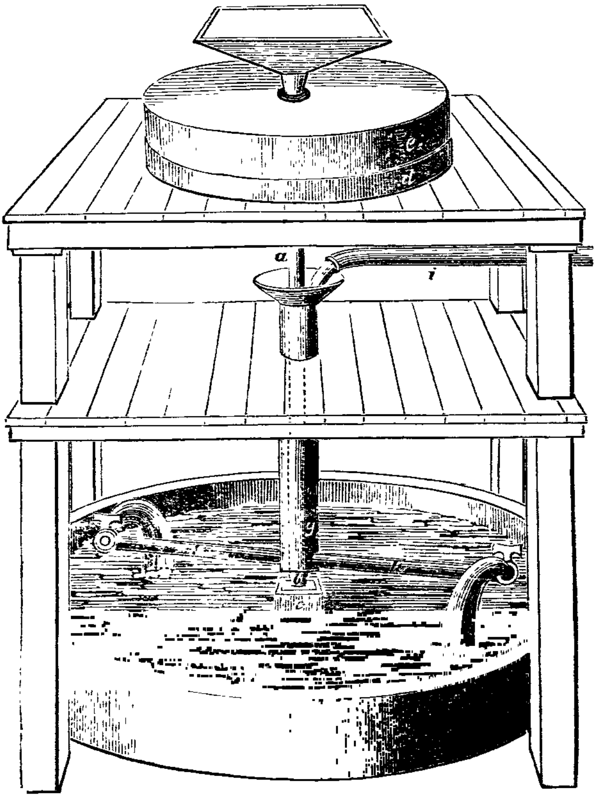
BARILLA. A substance imported, in considerable quantities, from Spain, and extensively used in soap-works, glass-works, and various other chemical arts. It is obtained by the incineration of the salsola soda, a marine plant, which is cultivated with great care in the neighbourhood of Alicant and Carthagena; that of Alicant is generally the most esteemed. An inferior species of Barilla is also manufactured in many parts of North Britain, from the salsola of Linnæus, or common sea-wrack, and forms such an important article of commerce, that it is said Lord Mac Donald, of the Isles, realizes 10,000*l.* a year from his kelp shores alone, which his ancestors looked upon as of no value whatever. The following account of the manufacture "*on the farm of Strond, in Harris*," possessed in tack by Mrs. Anne Campbell, is taken from the Transactions of the Highland Society of Scotland. "1. The ware is cut off the rocks with a common hook, similar to those used for reaping, but stronger, and having a rougher edge. It is then landed on a clean spreading ground, and if any sand or mud adhere to the weed, it is carefully washed before landing. The ware, or weed, is then spread out every dry day, and made into small cocks at night; and when it is found to be pretty dry, it is made into larger cocks, and left to heat for six or eight days; after which, a dry day, with a good breeze of wind, is selected for burning it; which operation is performed in kilns, constructed roughly of middle-sized stones, the outside being covered with turf; the length of each kiln is from 15 to 18 feet; breadth, 2½ feet; and height, 2 feet. The process of burning is as follows:—A small bundle of straw, or heather, is set on fire; the driest part of the ware is placed over this, and gradually added until the flames become general through the kiln; then the ware to be burnt is thrown in, little by little, till the whole is reduced to ashes. If, however, it happens that the day is too calm, or that the ware is not sufficiently dry, so that the ashes cool and cake into white crusts, the manufacturer stops burning any more until he rakes all the ashes out of the kiln; he then commences burning again, and goes on in this way until the whole is thoroughly burnt. The last process is the raking or working of the ashes with an iron with a wooden handle, made for the purpose, until the whole is brought into a vitrified state; the mass is afterwards broken into pieces of about 2 cwt., in which state it is ready for shipment.

BARIUM. A metal discovered by Sir H. Davy, in the earth barytes, in which it is combined with oxygen, thus constituting a metallic oxide. The following is the mode of obtaining it: take pure barytes, make it into a paste with water, and place it on a plate of platina. Form a cavity in the middle of the barytes, and in it drop a globule of mercury. Touch the globule with the negative wire, and the platina with the positive wire, of a voltaic battery of about 100 pairs of plates in good action. In a short time, an amalgam will be formed consisting of mercury and barium. This amalgam must be introduced into a bent glass tube, filled with the vapour of naphtha, and the end must then be hermetically sealed; heat being applied to the received end in which the amalgam lies, the mercury will distil over, leaving the barium, which is of a dark grey colour, and of a lustre inferior to cast iron. Dr. Clarke asserts, that he obtained metal by exposing pure barytes to the flame of the oxy-hydrogen blow-pipe, but no one has since succeeded in the experiment, and it is generally believed that the Doctor was mistaken, and that the globules which he formed, owed their lustre and polish to the fusion the earth had undergone.

BARK. In Botany, the outer skin or covering of trees, the ingredients composing which vary much in the different species, which are, accordingly, applicable to various purposes of the arts. Some are highly medicinal, as Jesuit's bark; some are used for tanning leather, as the bark of the oak and Spanish chesnut, &c.; some in dyeing, as the bark of alder and walnut trees; some afford spices, as cinnamon, and cassia lignea; and others are applicable to divers uses, as the bark of the cork tree. The Japanese make paper of the bark of a

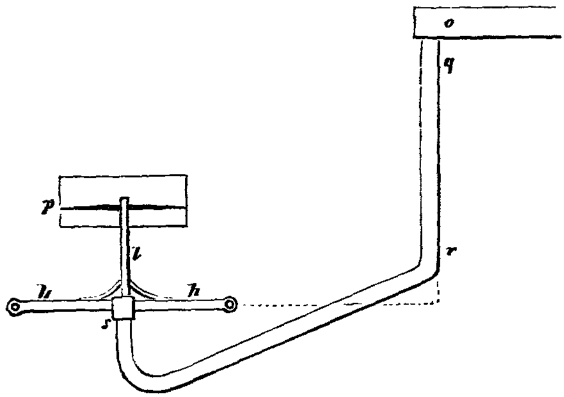
mulberry tree; and in Otaheite, a species of cloth is made from the bark of the paper mulberry tree, of the bread-fruit tree, and of the cocoa-nut tree.

BARKER'S MILL. A simple and ingenious hydrostatic machine, invented more than a century ago, by Dr. Barker, and forming one of the most simple water mills ever constructed. It has been rarely introduced in practice, although it has been warmly eulogized and recommended by most writers on the subject of hydraulics. In the annexed engraving, which is a perspective view of the machine,



a b represents a vertical axis, moving on a pivot at *b*, which would be best made of steel, and to run in a brass step let into a block of stone, as at *c;* this axis passes freely through the lower mill-stone *d*, and is then fixed to the upper stone *e*. To the axis is also fixed the large vertical tube *g*, the upper part of which is expanded into the shape of a funnel or basin, for receiving the water from the mill-course or pipe *i;* at the lower part *g*, this tube has an open communication with the hollow horizontal arms *h h*, each of which has an opening near its extremity on one side, and so adjusted by stop-cocks for regulating the discharge, that the vertical tube shall always be kept full of water, in order that the utmost force may be obtained, as a lateral pressure will be exerted in all directions in the horizontal arms, proportionate to the altitude of the column. Now this pressure being removed from the space forming the area of the aperture of the arms, by the water being allowed to issue through it, there will be an excess of pressure on the opposite side of the arm, in which there is no pressure equal to the force with which the water would spout from the aperture, were the machine fixed, and the water permitted to pass through it. In the preceding form of Barker's mill, the length of the axis must always

exceed in height the elevation of the pipe *i*, which in some cases might render the execution of such a machine difficult. To remove this difficulty, it was proposed by M. Mathon de la Cour, in Rozier's *Journal de Physique*, for August, 1775, to introduce the water from the mill course into the horizontal arms *h h*, which are fixed to an upright spindle *l*, as represented in the annexed diagram, and without any revolving vertical tube, as in the previously described arrange-



ment. The water will now obviously issue from the apertures at the extremities of *h h* in the same manner as if it had been introduced at the top of the tube, in the former figure; hence the spindle may be made as short as we please. The practical difficulty, in this arrangement, is to give to the arms *h h* a motion round the mouth of the feeding pipe, which enters the arms without any great friction, or any considerable loss of water. In this form of the mill, *o* is the reservoir; *p* the mill stones; *l* the vertical axis; *q r s* the feeding pipe, the mouth of which enters the horizontal arm at *s*. In a machine of this kind, constructed at Bourg Argental, the tubular arms *h h* were each 46 inches long, and their inside diameter 3 inches; each of the orifices $1\frac{1}{8}$ inch diameter, and the height of the head of water above the points of discharge was 21 feet. Though the fall was so great, the consumption of water was small, since it was supplied by a 2-inch pipe; and when the machine was not loaded, and had but *one* orifice open, it made 115 turns in a minute. Thus a prodigious centrifugal force is produced in the arms, and a corresponding velocity far exceeding that of a simple fall of water with a pressure of 21 feet head. The machine, when empty, weighed 80 lbs., and it was half supported by the upward pressure of the water. It is to be regretted that no extensive and accurately conducted experiments have been instituted to determine the comparative powers of this machine, and that great difference exists in the opinions both of theoretical writers and practical engineers upon the subject. L. Euler, J. Bernoulli, and A. Euler, consider it to be the most powerful of all hydraulic machines. Whilst the Abbé Bossut reckons the overshot-wheel as upon the whole superior to it, Mr. P. Ewart says, that "the effect of this mill is much superior to that of an under-shot water wheel, consuming the same quantity of water, but inferior to that of an over-shot wheel, in which the water is applied to the best advantage; but Mr. Waring makes the effect to be equal only to that of a good under-shot wheel, when driven by an equal quantity of water falling from the same height.

BARK STOVE is a kind of hot-house, containing a bed of tanners' spent bark, mixed, according to circumstances, with a proportion of earth and other matters; in which are placed the plants, in pots or otherwise. The bed is usually gently heated from a flue underneath, which together with its disposition to ferment of itself (when kept moist), forms a powerful stimulant to accelerate and perfect the growth of exotic plants.

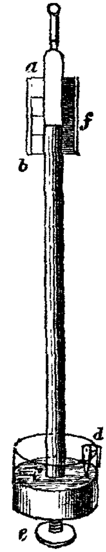
BARLEY. A well known kind of grain, chiefly used in this country in the

preparation of malt, for which see MALTING. The meal is also used in bread and soups. Whiskey, gin, and other spirits, are distilled from it. The barley-sugar of the shops is merely sugar boiled in barley-water to a consistency that will cause it to solidify in the cold state; it is poured upon a stone slab, anointed with oil of sweet almonds, rolled out into little cylinders, and twisted.

BARM, or YEAST, is a substance which separates under the form of a froth, more or less viscid, from all the juices and infusions which experience the vinous fermentation. It is commonly procured from the beer manufactories, and is hence called the barm of beer. If left to itself for some days, in a close vessel, at a temperature of from 55° to 70°, it is decomposed, and undergoes the putrid fermentation. To prevent this decomposition, it is the custom, in Paris, to evaporate it to a solid form, in which state it is sold under the name of *levure*, which article, however, comprises not only yeast, but the bottoms of the beer in the working-tun and store-casks. This is purchased by the yeast merchants, the beer drained from it through sacks, and the remainder of the beer washed out by putting the sacks in a stream of water; the solid matter left in the sacks is then dried in the open air. The true yeast, or froth of the beer, is also dried for use in the same manner, as the bakers in Paris prefer it in a solid state. Dry levure ought to be yellow, brownish, or greyish white, by no means black or bitter. It should not yield to pressure by the fingers, and be equally dry throughout, so as to break with a smooth surface. When dissolved in hot water, and a few drops of the solution are poured into boiling water, they should immediately rise to the surface. See BEER, and BREAD.

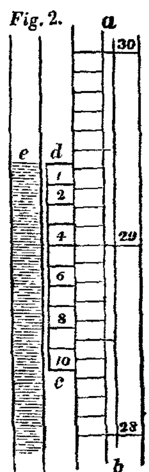
BAROMETER. An instrument by which the pressure or elasticity of the air is ascertained. It consists essentially of a glass tube, not less than 34 inches in length, closed at one end. The tube is completely filled with mercury, and then inverted in a cup or box of the same metal. By inverting the tube, a portion of the mercury will fall out, but a column varying in height from 28 to 31 inches above the surface of the metal will still remain, and which, being supported by the pressure of the air, will be an indication of its amount at the time. The barometer has assumed a variety of forms, the construction of the most important of which we shall endeavour to explain; but we deem it necessary, previously, to enter a little more minutely into the nature and operation of that form of the instrument to which we have just referred. The common barometer was the discovery (for it can scarcely be called an invention) of Torricelli, a disciple of the celebrated Galileo. It is, from this circumstance, frequently called the Torricellian tube; and the vacuous space above the surface of the mercury in the tube, is called the Torricellian vacuum. In the construction of the barometer, the principal object to be attained is a perfect vacuum in the upper part of the tube. To effect this, we must first make the tube perfectly free from moisture by exposing it gradually to the heat of a charcoal fire. The tube must have a bore sufficiently large to render the effect of capillary attraction insensible. The mercury employed to fill the tube must be rendered as pure as possible, by pressing it through the pores of chamois leather, and afterwards distilling it. A small portion of the purified mercury may now be put into the tube, and heat gradually applied to it, till the mercury boils. Another portion may then be added, and boiled in a similar manner; and this process continued till the tube is completely filled. By these means, the mercury itself will be purged of any air it may have acquired, and the air which adheres to the sides of the tube will also be effectually expelled. If the tube be now inverted into a cup or other vessel of mercury, the barometer, as far as its construction is concerned, will be complete. In the annexed cut, $a\,c$ represents the barometric tube inverted in its cup. The mercury has subsided to the point f; and the next object is, to ascertain the precise length of the column from c to f. For this purpose, a scale $a\,b$ is attached to the barometer near the top. In the ordinary use of this instrument as a weather-glass, the rise and fall of the mercury seldom exceeds a range of 3 inches, the height of the column varying with the atmospheric pressure from 28 to 31 inches. If, therefore, a scale of about 4 inches long, carefully graduated to tenths of an inch, be attached at the height that accords with the number of inches we have mentioned, it will be sufficient to

Fig. 1.



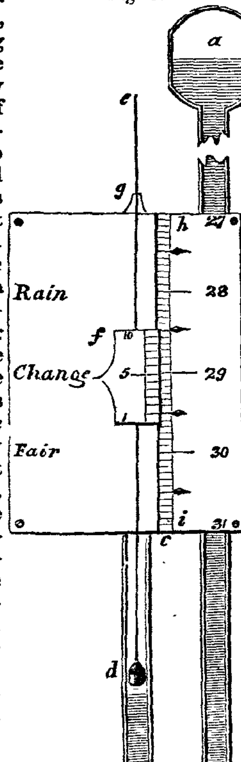
determine the ordinary changes of atmospheric pressure. There is, however, one circumstance to which it is necessary to attend, in measuring the height of the mercurial column. It will be seen, that as the column *f c* falls, it will necessarily raise the level of the fluid in the cistern; and contrariwise, when the column rises, it will depress the level of the cistern. On this account, the initial point of the scale is perpetually changing its position, and, consequently, the numbers on the scale cannot indicate the true distance between the surface of the mercury in the cistern and that of the supported column. To obviate this inconvenience, the horizontal sectional area of the cup is made considerably greater than a like section of the tube, by means of which a considerable fall in the tube produces but an inconsiderable alteration in the level of the fluid in the cup. For example, if the diameter of the tube be $\frac{1}{4}$ of an inch, and that of the cup be 2 inches, the respective areas will be as $\frac{1}{16}$ to 4, or as 1 to 64; hence a fall of 1 inch in the tube will cause a rise of $\frac{1}{64}$ of an inch in the cup. In ordinary observations, this degree of accuracy would be sufficient; but in the nicer operations of science, a greater degree of precision is essential; hence different contrivances have been employed for the purpose of ascertaining more exactly the difference of levels. The most general mode of effecting this object is to make the bottom of the cistern movable, so as to be raised or depressed by means of a screw *e*. An ivory index *d* may be attached to the top of the cup, and which being finely pointed at the lower end, will serve to indicate a fixed level. Before an observation is made with the barometer, the screw *e* is turned until the surface is brought exactly to coincide with the point of the index, by raising or depressing the bottom according as the surface was below or above that point. By this means, the surface of the mercury always stands at the same level, and hence the divisions on the scale *a b* will represent the actual changes in the height of the barometric column. Having attained a method of fixing the initial point of the scale, the next object to be attained is a means of reading off its indications with the utmost precision. In our description, we have supposed the scale divided into tenths of an inch, but this is not sufficiently accurate for experimental research. It would therefore be necessary to divide each of these tenths into hundredths of an inch, and adapt a small microscope to the instrument, in order to obtain the precise height of the column. The usual mode, however, of obtaining these smaller subdivisions of the scale, is by means of a vernier, or small graduated plate, which is movable by a screw, or otherwise, on the divided scale of the barometer. The principle of the vernier will be seen by reference to the accompanying engraving. Let *a b* represent a portion of the scale divided into tenths of an inch; let *c d* be the sliding scale, or vernier, equal in length to 11 divisions on the principal scale, but divided into only 10 equal parts. From this arrangement, it will be seen that every division on the vernier will be the tenth part of 11 tenths of an inch, or every division is equal to 11 hundredths of an inch, and, consequently, every division on the vernier exceeds, by one hundredth of an inch, every division on the principal scale. Suppose the vernier placed, as in the diagram, so that its upper edge *d* may be exactly even with the surface *e* of the mercury in the tube. If we examine the principal scale, we shall perceive that the mercury stands somewhat higher than 29 inches and 4 tenths. If we now look at the vernier, we shall find that the division 4, on its surface, coincides with a particular division on the scale. Now, as we have seen that each division on the vernier is one hundredth of an inch greater than one division on the scale, it follows that the space from 29 up to the level of the mercury, is 4 tenths and 4 hundredths of an inch,

Fig. 2.



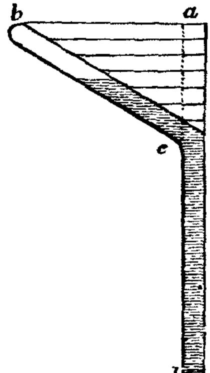
and, consequently, the true altitude of the column is 29 inches, 44 hundredths. In using the vernier, considerable precision must be employed in making its upper edge a tangent to the curved surface of the mercury in the tube, and, consequently, its accuracy will still depend upon the skilful manipulation of the observer. To obviate this, and render the barometer self-regulating, Mr. Christie, Secretary to the London Mechanics' Institution, has invented and constructed a barometer, in which, by means of a float, the vernier is set at its proper height by the rising or falling of the mercury itself. The annexed sketch will show in what the improvement consists. Here *a b c* represents a glass barometer tube about 35 inches long, exclusive of the part *b c*. It is not less than a quarter of an inch diameter inside, and enlarged at the top *a* to about two inches. On the surface of the mercury, shown by the shading, rests a small glass ball, or float *d*, supporting a slender steel wire, *d e* with its attached vernier *f*. This wire passes loosely through a guide hole in the projection *g* to keep it close to the scale of inches *h i*. In other respects, the scale and vernier are similar to those of the common barometer. The upper part of the enlarged tube being vacuous, the mercury is prevented from descending by the pressure of the atmosphere on the surface at *d;* and as the pressure increases, it will force down the mercury in the part *c b* of the tube, and, consequently, cause it to rise in the leg *a b*. As the surface at *d* falls, the float carrying the vernier falls with it, and thus the edge of the vernier being always kept at a given distance from the surface of the mercury, will indicate the precise amount of any changes that may occur in atmospheric pressure.

Fig. 3.



In order to increase the extent of the barometric changes, a contrivance is sometimes adopted, called the diagonal barometer, which is represented in *Fig.* 4. *b c d* is the glass tube bent at *c*, the altitude of which is less than 28 inches; hence *c b* includes the whole barometric range in the present form, while *a c* is the range it would have were the whole of the tube vertical. Now it is manifest, that by decreasing the angle at *c*, so as to bring *b c* nearer the horizontal position, we can make its proportionate length to *a c* as great as we please. Suppose *b c* so inclined that its length shall be three times greater than *a c*, then every rise or fall of 1 inch in *a c* would be equivalent to a rise or fall of 3 inches in *b c*. The difficulty, however, of observing the precise height of the mercury in this arrangement, more than counterbalances the advantage resulting from the extended range, and this form is, therefore, seldom adopted.

Fig. 4.



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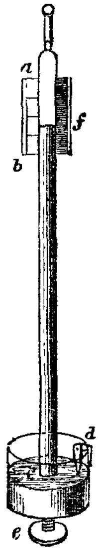

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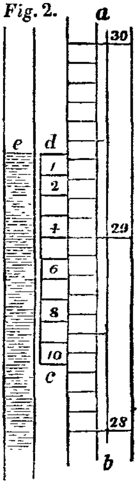

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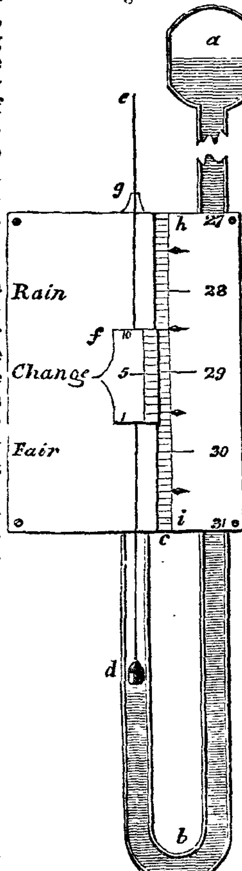

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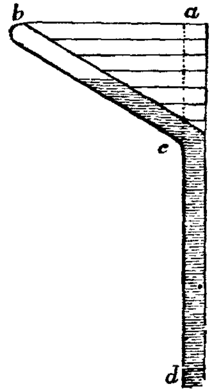

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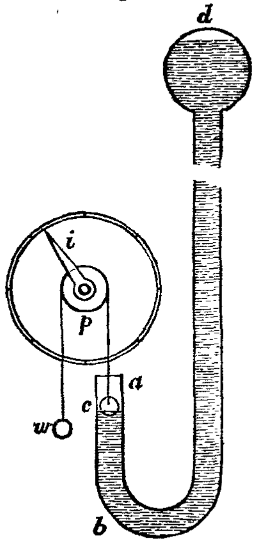
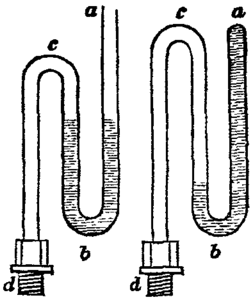
changes of altitude occur: for as the diameter of the bulb *d* at the top is very large, compared with the diameter of the tube at *c*, a small fall in *d* will be equivalent to a considerable rise in the tube *a b*. Thus the surface at *c* may rise 3 inches, and thereby shorten to that amount the distance between the two surfaces of the column, which is the true height sustained by atmospheric pressure, without sensibly affecting the level at *d*. At *c* there is an iron ball, floating on the surface of the mercury, and partly supported by means of a thread passing over the pulley *p*, and carrying a small counterpoise at *w*. On the axis of the pulley, an index *i* is fastened, which moving with it, branches the circumference of the circular plate, on which a scale is drawn, to represent the rise or fall in inches; and also the terms *fair*, *change*, *rain*, *&c.*, which certain altitudes have been improperly considered to indicate. In this arrangement, it is manifest that as the column is supported by the air's pressure on the surface *c*, any diminution of that pressure will cause the mercury in the longer leg to fall, and that in the shorter to rise. On the other hand, if the atmospheric pressure increases, the mercury will rise in the longer, and fall in the shorter, leg; but, as before observed, the change of level will be scarcely perceptible in the former, on account of the enlarged diameter of the upper part. The changes, then, that occur in the shorter leg, may, without material error, be considered the representatives of the changes that are continually occurring in the atmosphere. Now it will be evident, on inspection, that as the ball *c* is partly supported by the mercury, it will partake of its motion. If the pressure of the air increase, the surface at *c* will be depressed, and as the iron ball must sink with it, the thread to which it is attached will, at the same time, communicate its motion to the pulley *p*, and through it, to the index, which will, consequently. move from the right towards the left of the graduated circle. On the other hand, if the atmospheric pressure decrease, the surface at *c* will rise, and, with the assistance of the counterpoise *w* force up the iron ball, and, by this means, turn the pulley and index in an opposite direction. There are two sources of error in this instrument, that render it inferior to the simple vertical barometer. These are, the pressure of the iron ball on the surface of the mercury, which necessarily increases the height of the shorter column, and the friction of the pulley. It is impossible entirely to annihilate these causes of error, and hence, for philosophical purposes, the straight barometer is preferred.

Fig. 5.



The *Syphon Barometer* is an instrument used to ascertain the pressure of air in the partially exhausted receiver of an air-pump. It consists of a tube bent as in the accompanying engraving, *Fig.* 6. Each leg may be about 4 inches in length, and one *a b* completely filled with purified mercury. When the instrument is connected with the air-pump by means of the screw at *d*, and the air partly exhausted, the mercury in the leg *a b* will begin to fall, and, consequently, rise in the branch *c b;* every inch, therefore, that it falls in *a b*, must be reckoned equal to two inches in the straight barometer. This instrument does not begin to act till the air is reduced to about $\frac{1}{7}$ of its original density; but this is no inconvenience, as its indications are seldom required till the exhaustion is nearly complete. If the leg *a b* be lengthened, and left open at the

Fig. 6.



top, as in *Fig.* 7, this barometer becomes a useful appendage to the steam engine, in ascertaining the pressure of steam within the boiler. When it is attached to the boiler by the screw *d*, and the air or steam in the boiler has the same elasticity as the external air, the mercury stands at the same height in both legs; but as soon as the steam increases in elasticity, the mercury will be depressed in the leg *c b*, and rise in *a b*, and the difference between the two levels will be proportional to the difference between the external and internal pressure. If the common barometer stands at 30 inches, and the difference of level between the two surfaces is 6 inches, the elasticity of the steam will be $\frac{6}{30}$ or $\frac{1}{5}$ greater than the pressure or elasticity of the atmosphere.

There are other forms of the barometer, but their comparative unimportance renders it unnecessary to describe them here. We shall, therefore, proceed to consider the most important purposes to which this instrument is applied.

The most immediate use of the barometer, for scientific purposes, is the ascertainment of the amount and variation of atmospheric pressure. The fluctuations in the pressure being observed in connexion with changes in the state of the weather, a general correspondence is supposed to prevail between these effects. The instrument has, from this circumstance, been called a *weather glass*. Rules have been attempted to be established, by which the approaching state of the weather may be predicted from the height of the mercury, and the words *rain*, *fair*, *changeable*, &c. are engraved on the scales of common barometers. These marks are, however, entitled to no attention, since it is the changes that occur in the height, and not the absolute height, that indicates approaching changes in the weather. The variation in the altitude of the barometer in a given place, together with the corresponding changes of the weather, have been regularly recorded for a considerable time; and it is by an exact comparison of these results that general rules are to be found. At present, the best rules are liable to some uncertainty at times. Those which have been considered least liable to error are the following: 1. Generally, the rising of the mercury indicates fair weather; its fall shows the approach of foul weather. 2. In sultry weather the fall of the mercury indicates coming thunder. In winter, a rise indicates frost. In frost, its fall indicates thaw, and its rise indicates snow. 3. Whatever change of weather suddenly follows a change in the barometer, may be expected to last but a short time. Thus, if fair weather follow immediately the rise of the mercury, there will be very little of it; and in the same way, if foul weather follow the fall of the mercury, it will last but a short time. 4. If fair weather continue for several days, during which the mercury continually falls, a long succession of foul weather will probably ensue; and again, if foul weather continue for several days, while the mercury continually rises, a long succession of fair weather will probably succeed. 5. A fluctuating and unsettled state in the mercurial column indicates changeable weather. The other important purpose to which the barometer is applied, is the measurement of altitudes. If the atmosphere were a liquid of nearly equal density, like water, the measurement of heights by the barometer would be the simplest process imaginable: for we should have then only to make one experiment to ascertain how much the mercury would fall, in rising to the height of 100 feet for example, and then the fall for 200 or 300 feet would, of course, be double or triple the former one. But the density of air is well known to decrease as we ascend from the earth, so that at the height of $3\frac{1}{2}$ miles, it is only one half its density on the surface of the earth. From this it must be evident that if the mercury fall one-tenth of an inch in rising through the height of 100 feet, we must rise through a greater height to cause a fall of another tenth. The height of the surface of the atmosphere above that of the earth is considered to be about 50 miles; and we have already observed, that at the height of $3\frac{1}{2}$ miles the density is reduced to one-half. Hence we should find, by ascending to the height of $3\frac{1}{2}$ miles in the atmosphere, the mercury would stand at one-half the height of another barometer at the surface of the earth. If, however, the decrease of density were affected by the height alone, the determination of altitudes would be comparatively easy, as a simple formula may be given, which would immediately show the relation between the height and density. The circumstance that

interferes with barometric observations, is temperature, which affects them in two ways. 1. Increase of temperature expands the mercury in the barometer, and thereby causes the column to be longer than at lower temperatures. 2. The air itself becomes expanded by heat; and hence the column becomes lengthened without any increase in its absolute weight. It might be thought that these effects were too trivial to influence sensibly the results of our observations; but it must be remembered, that as we ascend from the earth, the temperature of the air rapidly decreases, so that at a certain height, dependent on the latitude of the place, a freezing temperature constantly prevails. Putting aside the effect of change of temperature, the simplest rule for determining heights is as follows:—Observe the height of the mercury at the bottom and top of the altitude to be ascertained; take the logarithms of these heights, and multiply their difference by 10,000, the product is the answer in fathoms. Then suppose the mercury at the foot of a mountain to stand at 29.5 inches, and at its summit 26.4 inches, the calculation would be as follows:—

Lower barometer. . .	29.5	log.	.469822
Upper ditto	26.4	log.	.421604
	Difference		.048218
			10000
			482,180,000 Fathoms,
			or, 2893 feet,

which is the altitude, supposing the temperature to be at 31° Fahr. If the temperature differ from this, it must be observed at the upper and lower station, and a mean of the two taken, by adding them together, and dividing the sum by 2. If the mean thus obtained exceed 31°, the altitude before obtained must be *increased* $\frac{1}{435}$ for every degree of difference between them, and *vice versa*. If we wish to correct the other error arising from the expansion or contraction of the mercury in the barometer, we must observe the temperature of the mercury at the upper and lower station; then the altitude of the lower one must be increased, or the higher one diminished, $\frac{1}{1600}$ part for each degree of difference between their temperatures. To those who are unaccustomed to the use of logarithms, the following rule may be preferred:—Take the sum and difference of the upper and lower barometric heights, and divide one by the other; multiply the quotient by 55000, and it will then answer in feet for a temperature of 55°. Suppose, as before, the height at the lower station to be 29.5, and at the upper, 26.4 then

$$\frac{29.5-26.4}{29.5+26.4} = 0554$$

And $.0554 \times 5500 = 3047$ feet.

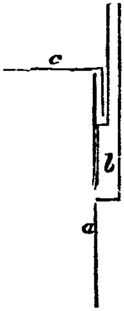
This result, it will be seen, exceeds the other by 154 feet; it is not so exact, but, in many cases, it may serve to furnish a tolerable approximation, when logarithmic tables are not at hand. The corrections for temperature may be applied as in the other formula.

BAROSCOPE. An instrument for shewing the weight of the atmosphere, frequently confounded with the Barometer: the former, however, only proves that the atmosphere has weight; while the latter determines its true quantity.

BARREL. This article, as made by coopers, is too well known to need a description; but the air and water-tight metallic barrels employed in the British navy for preserving provisions, from their peculiarity of structure and utility, require a place in this work. Those which we shall describe are of the most improved kind, and were patented by the late Mr. Robert Dickenson, of the Eagle Foundry, Southwark. These barrels are made of wrought iron, of a cylindrical form, with a seam, soldered or rivetted, in the usual way. To strengthen the figure, and adapt it for the reception of the heads, a strong iron hoop is rivetted to each end of the cylinder. These hoops are prepared at the iron works, by rolling them into the form of a rebate, shown in section at *b*, *Fig.* 1. By this diagram it is also shown that the hoop is fastened with its thickest part against the side of the barrel *a*, about an inch below the extreme edge of the same; thus forming a deep groove between the sides of the barrel, and the thinnest

part of the rebated hoop, for the reception of the flange of the head *c*, which appears to be made by bending the periphery of the circular iron plate to a right

Fig. 1.



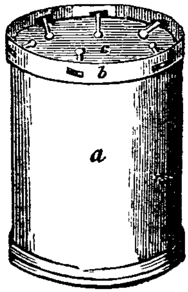
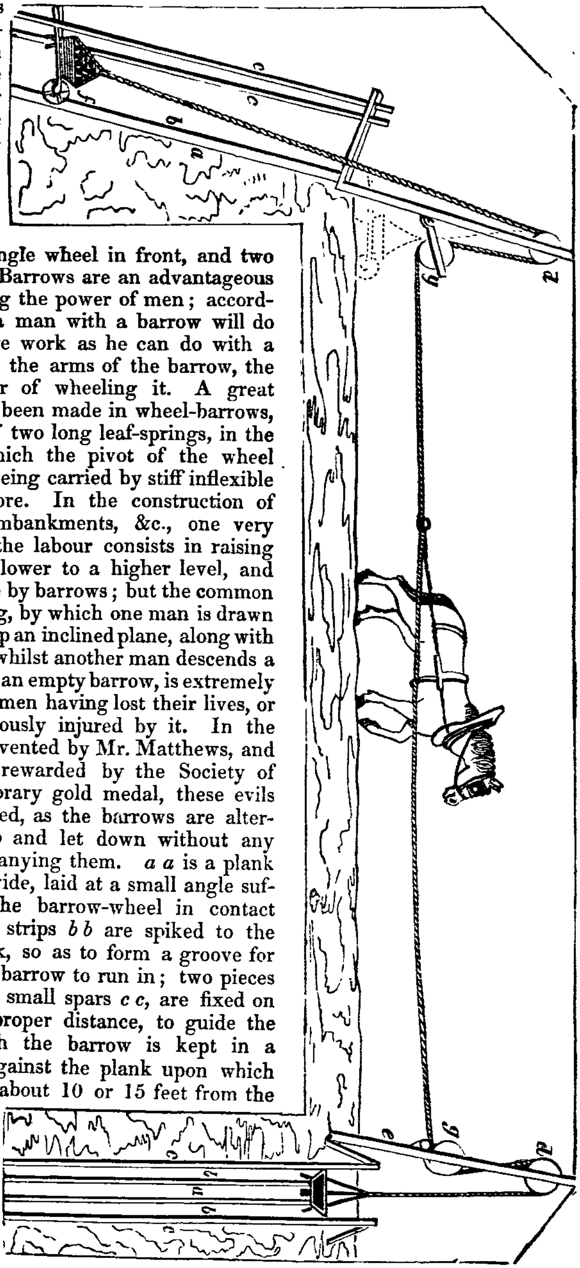


Fig. 2.

angle with its plane. Previous to the driving down of this head, a sort of packing, composed of hemp-bands, or currier's leather-shavings, is to be rammed into the groove, so as effectually to exclude both air and moisture. To secure the bottom head in its place, the thin projecting edge of the hoop is to be hammered down upon the bottom, and over this is to be rivetted a flat iron ring, to serve the purpose of the ordinary chimes of barrels, the exterior edge of which should extend a little beyond the periphery of the cylinder, to defend the sides of the barrel in rolling it. The upper head of the barrel is so constructed as to be removable at pleasure, the hoop which circumscribes it being the same as that on the bottom; but, instead of being hammered down, it is left erect, as shown at *Fig.* 2. The head is placed also within a similar groove, and is fastened down by means of a number of latch-bolts. These latch-bolts are attached to the head, or movable cover, by means of a pivot at one end, upon which they turn, and are driven sideways into long slots made through the projecting hoop, which slots are not made in a parallel line with the top of the cask, but aslant, so that when the latch-bolts are driven into them by a hammer, they draw the flanged head into the deep groove, which, being previously packed in the manner before-mentioned, makes the junction perfectly air and water-tight. This kind of cover, likewise, admits of its being very readily removed, by driving back the latch-bolts with a hammer; and the inconvenience formerly experienced in the smallness of the apertures in air-tight vessels, is herein completely removed, the opening being as wide as the barrel itself, so that larger matters may be stowed in it, and the packing and removing of the contents greatly facilitated. Metal casks, heretofore employed for similar purposes, were usually coated with paint to prevent oxidation, and render them water-tight, which was found to communicate a bad flavour to the flour, biscuit, or other materials which they contained. To remedy this inconvenience, the patentee coats the barrels, both inside and outside, with any of the well-known waterproof compositions, which, while they effectually prevent oxidation, will not communicate any unpleasant taint to the articles of food, even in the hottest climates. The patentee has selected the following:—To 1 pound of caoutchouc (Indian rubber) add 8 oz. of black resin, and 2 oz. of Venice turpentine; let the caoutchouc be cut into small pieces, and expose the mixture to a heat of 160° for the space of 24 or 36 hours. When dissolved, it is to be spread upon canvass, or other fibrous material, and then passed between cylindrical rollers to give it an even consistency. With this material the barrels are to be coated both within and without, except in the case of dry goods, such as biscuits, flour, &c., when the coating of the exterior alone is considered sufficient, and the interior surface of the iron may be bronzed in the same manner as gun-barrels. For oils, tar, varnish, &c. the insides of the barrels have no coating, those materials being, of themselves, preservatives against oxidation. In some cases of dry goods, the inside may be coated with the thinnest and cheapest woven material, or even paper; and these may be attached, by any cheap kind of cement, that will effectually exclude the air and moisture.

BARROW. A machine for carrying loads by manual labour. Barrows are of two classes: hand-barrows, and wheel-barrows. Hand barrows consist merely of a small platform attached to two poles projecting equally from each end, and carried by two men in the manner of a sedan chair. Wheel-barrows are made of various forms, widely differing from each other, to suit the particular work for which they are intended, as excavator's barrows, brickmaker's barrows, &c., but all of them are constructed with a single wheel in front, and two handles behind. Barrows are an advantageous mode of employing the power of men; according to Coulumb, a man with a barrow will do half as much more work as he can do with a hod. The longer the arms of the barrow, the less is the labour of wheeling it. A great improvement has been made in wheel-barrows, by the addition of two long leaf-springs, in the outer end of which the pivot of the wheel turns, instead of being carried by stiff inflexible arms, as heretofore. In the construction of docks, canals, embankments, &c., one very great portion of the labour consists in raising the earth from a lower to a higher level, and this is mostly done by barrows; but the common mode of barrowing, by which one man is drawn almost vertically up an inclined plane, along with a loaded barrow, whilst another man descends a similar plane with an empty barrow, is extremely dangerous, many men having lost their lives, or having been seriously injured by it. In the following plan, invented by Mr. Matthews, and which has been rewarded by the Society of Arts, by an honorary gold medal, these evils are entirely avoided, as the barrows are alternately drawn up and let down without any workman accompanying them. *a a* is a plank 10 or 11 inches wide, laid at a small angle sufficient to keep the barrow-wheel in contact with it, and two strips *b b* are spiked to the edge of the plank, so as to form a groove for the wheel of the barrow to run in; two pieces of quartering, or small spars *c c*, are fixed on each side, at a proper distance, to guide the handle, by which the barrow is kept in a proper position against the plank upon which the wheel runs; about 10 or 15 feet from the top of the plank, and the stage where the loaded barrow is to land, a pulley *d* is fixed to a pole *e*, through



which the rope, or chain, is passed down to the barrow; to the end of the rope is fastened a hook, which goes into an eye *f* fixed upon the point of the barrow. A pair of slings are slid upon the handles of the barrow, previously fastened upon the rope at a proper distance, to keep the barrow in a right position to be drawn up the plane, or plank, which is when the handles of the barrow are a little below the horizontal line with the wheel of the barrow while running up the plank. The rope, after passing over a pulley *d*, passes through another leading pulley *g*, at a proper height to suit the draft of a horse, and is connected to a similar apparatus at another inclined plane, situated at a distance from the former, somewhat exceeding the length of the planes on which the barrows run. A horse is attached by a rope to the middle of the horizontal part of the rope *g g*, and alternately traversing between the two stations, raises a loaded barrow at one station, or plane, whilst an empty one descends at the other, unaccompanied by a man. The pulley *d* is elevated so high as to let the rope from the barrow clear the bank, and yet incline so much inward that the barrow clears the bank as it swings in, and lands itself as shown by the dotted lines. The man has only to fix the ropes to the empty barrow, and wheel the full one away.

BARYTES. An alkaline earth, most commonly found combined with sulphuric acid, forming sulphate of barytes, or heavy spar. The experiments of Sir H. Davy show barytes to be an oxide of a metal to which he gave the name of Barium, which see. See also CHEMISTRY.

BASALTES, in Natural History, a heavy hard stone, most commonly black, or greenish, consisting of prismatic crystals, the number of whose sides is uncertain. It is distributed over the whole world, but nowhere exists in greater variety than in Scotland. A celebrated range of columnar basalt exists in Ireland, and is known by the name of the Giant's Causeway. It consists of three piers of three columns, which extend several hundred feet into the sea. These columns are, for the most part, hexagonal, and fit very accurately together, but, generally not adherent to each other, although water cannot penetrate between them. Basaltes, when calcined and pulverized, forms a good substitute for puzzolana, in the composition of hydraulic cement, having the property of hardening under water; and it has also been converted into glass, from which wine bottles have been manufactured.

BASE is a term usually applied to the lowest part of any thing; thus, in Geometry, it is the lowest side of the perimeter of a figure; in Architecture, the lowest part of a column, or pedestal; in Building, the lowest apartment is also called the *basement.*

BASE, in Surveying, is a line measured with the greatest exactness, on which a series of triangles are constructed, in order to determine the position of objects and places.

BASE, in Chemistry. Any body which is dissolved by another body, which it receives and fixes, and with which it forms a compound, may be called the base of that compound. Thus, for example, the base of neutral salts, are the alkaline, earthy, and metallic matters, which are saturated by the several acids, and form, with them, these neutral salts.

BASKET. A fabrication woven of straw, rushes, canes, and other elastic materials; but, in this country, principally of willow; which last, according to their growth, are called osiers and sallows. Osiers for white work are deprived of their bark by an instrument called the braker, and afterwards are cleaned by a common knife. They are then exposed to the sun and air in order to dry them thoroughly; after which they are housed, and kept carefully from moisture, which, if attended to, will preserve them for years. The same precautions against moisture are necessary for preserving osiers with their bark on. When these osiers are intended to be used, they are soaked for a few days, according to their age and dryness. Osiers deprived of their bark are assorted by the basket-maker into large and small rods, according to the work for which they are intended; the larger ones forming the slat and skeleton of the basket, and the smaller ones for weaving the bottom and sides. For common work, such as clothes-baskets, market-baskets, &c., the rods are used whole; but, for the finer

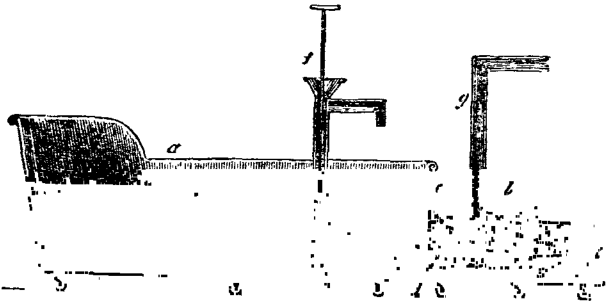
work, as table-mats, fruit and work baskets, and the like, the osiers are divided into four parts, lengthways, which are called splits, and these are afterwards reduced to various degrees of fineness, when they are called skeins. The method of making a basket of the ordinary kind is as follows:—The workman having cut off the large ends of as many osiers as he deems necessary, and of a length somewhat more than the width of the bottom, lays them on the floor in pairs, all ranging the same way; he then places on them two of the longest osiers, with their largest ends towards him, crossing the direction of the former; on the large ends of the two long osiers he places his foot, weaving each alternately under and over the short ends, which confines them in their places, and forms what is called the slat, or slate, which is the foundation of the basket. He next takes the long end of one of the two rods, and proceeds to weave it under and over the pairs of short ends all round the bottom, until he has wove the whole of it; this is, likewise, done with the remaining osier, and after this is exhausted, other long osiers are wove in, until the bottom is of a size sufficient for the intended basket. The workman next proceeds to sharpen the ends of as many long and stout osiers as may be necessary to form the ribs, or skeleton of the basket; the sharpened ends are planted, or forced, between the rods of the bottom, and are turned up in the direction of the sides, and the other rods are woven in and out, between each of the uprights, until the basket is raised to the intended height. To finish the edge, or brim of the basket, the ends of the ribs, which are now standing up perpendicularly, are turned down over each other in a manner easily understood by inspecting a basket, although difficult to describe. There remains only to add the handle; this is done by planting or forcing down close to each other, between the weaving of the sides, two or three osiers, cut to a proper length; when in their place, a hole is made through them, about two inches from the brim, into which a pin is put, to prevent their being drawn out; they are then covered, or bound together with skeins, sometimes of various colours, forming different kinds of platting on the handle. Basket-work is well adapted to many other purposes than those to which it is at present applied, as it combines, in an eminent degree, the three qualities of strength, lightness, and elasticity.

BASSOON, a musical wind instrument, blown with a reed, furnished with eleven holes, and used as a bass to hautboys, flutes, &c.

BASSORINE. A name given to a substance which is extracted from the gum resins, by successively treating them with water, alcohol, and ether. The bassorine being insoluble in these liquids, remains mixed merely with the woody particles, from which it is easy to separate it by repeated washings and decantations, because one of its properties is to swell extremely in the water, and to become very buoyant. This substance swells up in cold as well as boiling water, without any of its parts dissolving. It is soluble, however, almost completely by the aid of heat in water sharpened with nitric or muriatic acid.

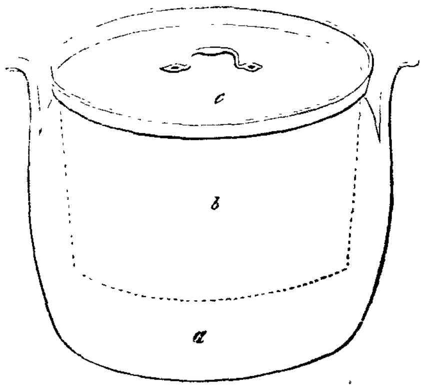
BATH. A receptacle of water in which to plunge, wash, or bathe the body. The practice of bathing, although not so common in this country as on the continent, is daily becoming more general; and, in most large towns, there are public establishments, where, at a very short notice, warm, cold, and vapour baths, either plain, saline, or medicated, may be had. From the beneficial effects of hot baths, in sudden cases of inflammation of the bowels, and of cholera, portable baths, of various kinds, have been constructed, by means of which a hot bath may be speedily prepared in a sick chamber; and the apparatus occupying but little space, can be easily stowed away when not in use. The annexed cut represents a simple and effectual apparatus of this description, invented by Mr. Benham, of Wigmore Street, Cavendish Square. *a* represents the ordinary bath filled with water to the proper height; *b* a furnace for heating the water; and *c* a fender to keep in the fuel and ashes; at the end *d e* the bath has a double case, at top and bottom of which there are apertures communicating with a double-cased boiler that entirely surrounds the fire. The water thus heated naturally ascends and enters the bath at *e*, while the cold water to supply its place enters the boiler at *d*; thus a continued circulation of the water is effected by this arrangement, so as to heat it very quickly, and by

a small fire, more conveniently and agreeably situated, than if placed under the bath as usual; *f* is a pump, the lower end of which dips into a small well at the bottom of the bath for discharging the water; *g* is a small wrought-iron flue; the whole runs upon castors.



In Mr. Hick's portable baths, a broad shallow flue of metal is constructed underneath the bath, and in the flue is ignited a determinate quantity of the oil of turpentine, or other inflammable liquid, supplied from a reservoir above, in the side of the bath, and regulated by a stop-cock. The vapour arising from the combustion is carried off by means of a tube, into the apartment in which the bath is placed. By a slight modification of the foregoing plan, the patentee purposes to employ the flame of condensed inflammable gas for heating the water rapidly; and in the water may be infused herbs, or other medicaments, for patients who may be labouring under cutaneous diseases. By these arrangements, a portable warm bath is prepared in a few minutes.

BATHS in Chemistry, a contrivance for subjecting different substances either to a steady heat, not liable to sudden fluctuations, or to a temperature which shall never exceed the boiling point of water. In the first case, the vessel containing the substance to be heated is imbedded in a vessel containing sand, or other slow conductor of caloric, and set in a furnace, and this is called a sand bath; but if it is desired that the temperature shall not exceed 212°, water is substitute for sand, and this is called a water-bath. A familiar example of a water-bath is the common glue-pot, which consists simply of a vessel containing water, in which is immersed another vessel containing the glue. Mr. Vazie recently patented culinary vessels on the same principle, an illustration of which is subjoined; *a* being the external vessel containing water; *b* the internal vessel containing the food; and *c* the cover. The principle of this method of limiting the temperature has received a more extensive application, by Messrs. Beale and Porter, who have obtained a patent for employing, as a heating medium,



various substances, which rise in vapour at different degrees of the thermometric scale, some exceeding, and others falling, below the boiling point of water, such as alcohol, ether, naphtha, turpentine, and various essential oils. Under the head BOILER will be found a description of an apparatus upon this principle.

BATTERING RAM. An ancient military engine, used for destroying the walls of fortified places, but which, since the invention of gunpowder, is no

longer used for that purpose, as, by means of cannon, the attack can be made from a much greater distance; but machines of this description are still sometimes employed in taking down old and massive walls. The battering rams of the ancients were of two kinds; the first consisted merely of a heavy beam, with a head of iron, which the soldiers bore in their arms, and assailed the walls by main strength. The second sort was much more powerful and effective. In these the beam was suspended by chains from a frame; the centre of gravity of the mass of the beam being pulled out of the perpendicular by ropes, they were suddenly let go, causing the head of the ram to strike the wall with a force proportional to the weight of the mass, and the space through which it moved. Some of these instruments were of enormous dimensions, and of immense power. That of Vespasian is said to have been 120 feet long, and to have weighed 100,000 lbs. The effect of some of these instruments, was much superior to any we can produce by our breaching cannon; for if the weight of a battering ram, moving with a velocity of 10 feet in a second, were no more than 170 times that of a cannon ball, moving at the rate of 1700 feet in a second, the momenta of both forces would be equal; but as the weight of these ancient machines was much greater than 170 times that of our heaviest cannon balls, their momentum, or impetus, to overturn walls, and demolish buildings, was much superior to that exerted by our modern artillery.

BEAM, in Building, a piece of timber resting upon walls, and used to support the floors or fronts of houses, to suspend weights from, &c. The strength of beams to each other is inversely as the length, and directly as the breadth and the square of their depth; their depth, therefore, is generally made greater than their breadth, as, by this means, greater strength may be obtained with less material; thus diminishing both the weight and the cost. Beams are variously named, according to the situations they occupy in a building. A tie-beam is a horizontal beam, extending from the opposite walls of a building, and having notches near the extremities against which the lower ends of the principal rafters of the roof abut, by which means the thrust of the rafters is exerted against the tie-beam, instead of acting against the walls. A girder is a stout beam, extending from one side of a building to the opposite one, and used to carry the joists: when the distance between the walls is great, it at the same time serves as a tie to the walls. A bressummer is a beam used to support a portion of a building above a considerable opening similar to a lintel over a door-way. When a beam projects from a wall, the outer end being unsupported, it is termed a cantilever. In cases where the distance between the points of support is great, and the load to be sustained by a beam is considerable, instead of a beam formed of one piece, a frame of timber, called a truss, is employed, which, in its simplest form, consists of two inclined beams, abutting against notches in a horizontal beam near its extremities; and the upper ends of the beams meeting in a point upon which the load rests, by which means the pressure is transferred from the centre of the beam, to the part of it which is over the points of support, and the stress upon the beam is changed from a transverse strain to a tensile strain, operating in the direction of the fibres. Roofs and centres of bridges are specimens of trusses, and are framed upon the same principle, although more complex in the form. The methods of forming trusses are very

Fig. 1.

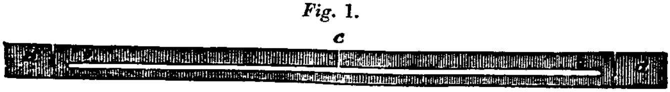
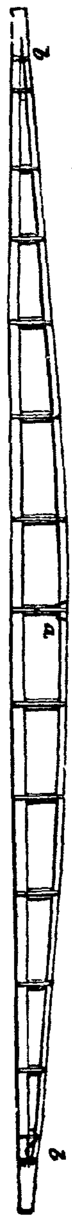


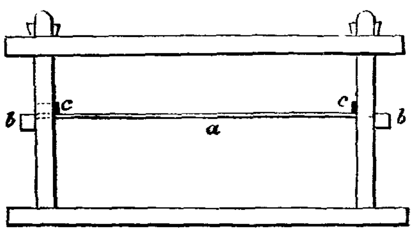
Fig. 2.

varied, depending partly upon the uses for which they are intended; the following description of a very neat, simple, and effectual method of constructing rafters for

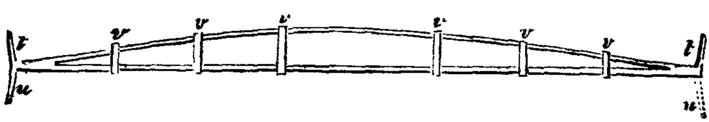
a nearly flat roof, invented by Mr. Smart, of the Ordnance Wharf, Westminster Bridge, is an extract taken from the inventor's communication to the Society of Arts. "I take a square spar of the usual size for a rafter, and, by means of a circular saw, make an incision in it as shown at *b b*, *Fig.* 1 page 156. I then make the cut *c* at right angles to the former, and equidistant from the two ends; lastly, I make the two cuts *d d*, taking out a thin wedge from each place. The two pieces *c d* are then to be gently raised up, till they form an angle of 10° or 12°, with the piece *b b*, and are secured in their place by the insertion of a key-wedge *e* of seasoned oak, as represented at *Fig.* 2. It is obvious that a weight pressing on the key-wedge of this rafter (the ends being properly supported), will be sustained till either the fibres of the wood forming the string are drawn asunder, or till the lateral cohesion of the wood forming the butt-ends of the rafters be destroyed: at the same time there is no lateral pressure on the wall." The above rafter is commonly known by the name of the "*Bow and String Rafter*."



Another rafter upon the same principle, by the inventor of the foregoing, is shown in the margin. The rafter, which is 56 feet between the bearings, is made out of a scantling 10 inches by 4. An incision is made by a circular saw, from the middle nearly to each end; a transverse cut is then made at *a*, through the middle of the upper part of it, and at each end *b b* of the incision, a transverse piece, of a wedge shape, is cut out, reaching nearly to the longitudinal incision, but not so near as to separate the parts. Short pieces of wood are then inserted between the upper and under part of the rafter, and the whole are secured by iron straps. It appears that Mr. Smart was led to the foregoing method of forming rafters, by the following experiment, which he made for the purpose of ascertaining whether the strength of a beam is increased in the proportion of three to two, as stated by Belidor, by fastening its ends so as to prevent their approach when loaded in the middle. He placed a lath, an eighth of an inch thick, in a strong frame, as shown by the annexed cut, which broke with a load of 11lbs. placed on its middle. He next took a lath of the same wood, and fixed it firmly at the ends, by means of the projecting pieces *b b* and the wedges *c c*, and ascertained that it would sustain, by this arrangement, a load of 270 lbs. whence it appears that the strength of the lath was increased nearly 25 times, by merely securing it well at the ends.

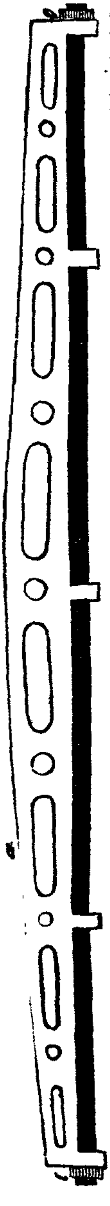


The following figure represents a trussed girder of wrought iron, similar in construction to the foregoing. This girder is made by welding an arched bar of wrought iron to a longer straight bar, and then turning the ends of this latter either up or down, as may be most convenient for the particular use to which the girder is to be applied. *t t* are the places where the bars are welded together that compose the girder; *u u* the ends of the straight bar turned either up or down. The arch is prevented from buckling, when the weight presses upon it, by means of blocks of well-seasoned wood, inserted at intervals between the two bars, and secured in their places by the iron straps



v v. Beams of wrought iron made in this way will, in Mr. Smart's opinion, support a weight so much greater than cast iron ones of equal dimensions, that they may be made of any given strength at half the cost of equivalent beams of cast iron.

The cut on the left represents one of the iron girders employed in building the London University. The whole length is 36 feet, and cast in one piece; it rises in the middle about 25 inches, and is provided with a wrought iron tie or



circular bolt of about 3 inches diameter, which passes through apertures in the series of projecting pieces shown, and is strongly screwed up at the ends *c c.* On each side of the girder are bolted wooden scantlings, into which the joists are framed.

Fig. 1

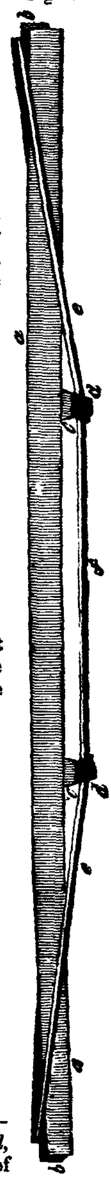


Fig. 1 represents a trussed girder, invented by Mr. J. Conder, on the principle of suspension; and *Figs.* 2, 3, 4, 5, represent separate parts of the plan of trussing, and the same letters refer to similar parts in all the figures. The girder *a a Fig.* 1 is furnished with cast iron plates, turned down at right angles, to extend over its ends. These end plates have on their upper surfaces circular hooked projections, shown in elevation by *Fig.* 2, and in plan by *Fig.* 3. The use of these

Fig. 2.

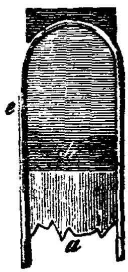
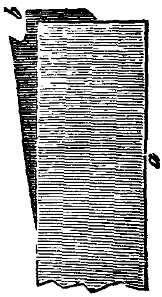


Fig. 3.



hooked projections is to receive round rods of wrought iron, bent in the middle to correspond and fit into the hooked projections, as represented by *b Fig.* 3. The

Fig. 4.

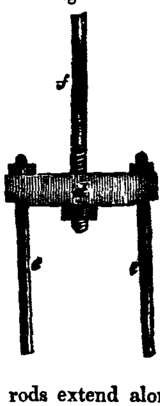
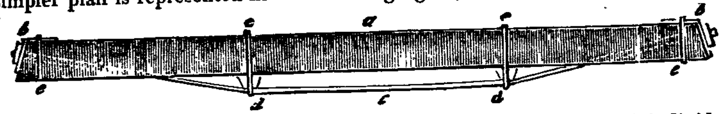


Fig. 5.

iron rods extend along each side of the girder one-third of its length, in a sloping direction from *b* to *d*, where their ends pass through holes in cross pieces of

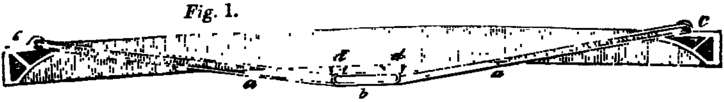
iron, and are secured by screwing thereon nuts, as shown at *Fig.* 4. Between the pieces *d d* and the lower side of the girder are placed prism-shaped blocks of oak *c c*, shown in section by *Fig.* 5, which vary in size according to the depth of the roof or floor which the girder is intended to support. Below the middle of the girder, and parallel thereto, extends a single rod *f*, equal in strength to a double rod *e e;* this rod passes through the middle of the cross pieces *d d*, and is secured by nuts screwed on its ends, as represented by *Fig.* 4. All the parts of the truss may be brought to any required tension, and the girder made to camber simply by screwing up one of the nuts on the rod *f*. A somewhat simpler plan is represented in the following figure, whilst it possesses the same



advantages as to strength and durability. The girder *d* to be trussed, is divided longitudinally into two flitches, and between them is introduced a single rod of iron *c*, the ends of which pass through the kneed plates *b b*, and are then secured by screwed nuts; the ends of the flitch are bevelled off at right angles, to the direction of the trussed rod. Beneath the girder are placed two triangular blocks *d d*, proportionate to the strength required. The two flitches are kept apart the thickness of the truss rod by the introduction of slips of wood between them, and kept in their places by straps at *e e e e*.

Mr. Renton's arrangement of the suspension trussed girder is shown in the figures beneath. *Fig.* 1 is an elevation of the truss, with one of the flitches removed

Fig. 1.



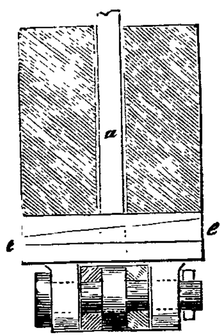


Fig. 2.

Fig. 3.

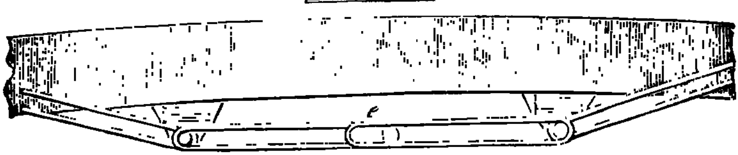


Fig. 4.

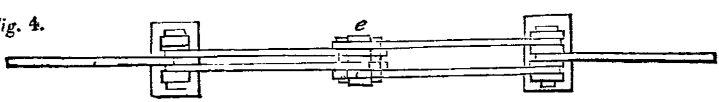
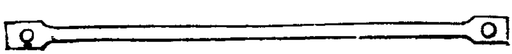
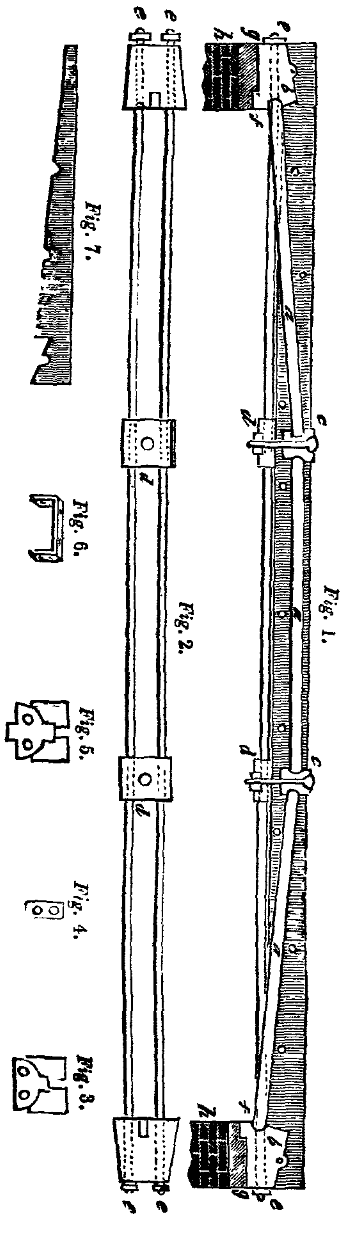


Fig. 5.



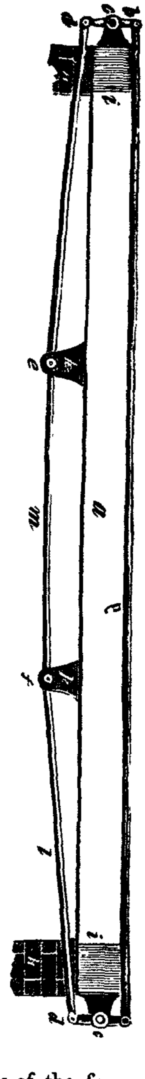
to show the iron work; and *Fig.* 2 is a section of the girder. *a a* the two suspension links, connected with the two tie links *b b* by bolts and keys, through the cast iron saddle pieces *d d*. The upper ends are united to the abutment pieces *c c* by bolts passing through them; the beam is adjusted to its bearing, or cambered, if necessary, by the folding wedges (seen at *e e Fig.* 2) at the back of the saddle pieces, which it may be found necessary to steady sideways by blockings spiked to the beams. *Figs.* 3 and 4, elevation and plan of another mode of connecting the tie links and adjusting them by wedges. *Fig.* 5, another form of link, which may be used, instead of the double bar link.



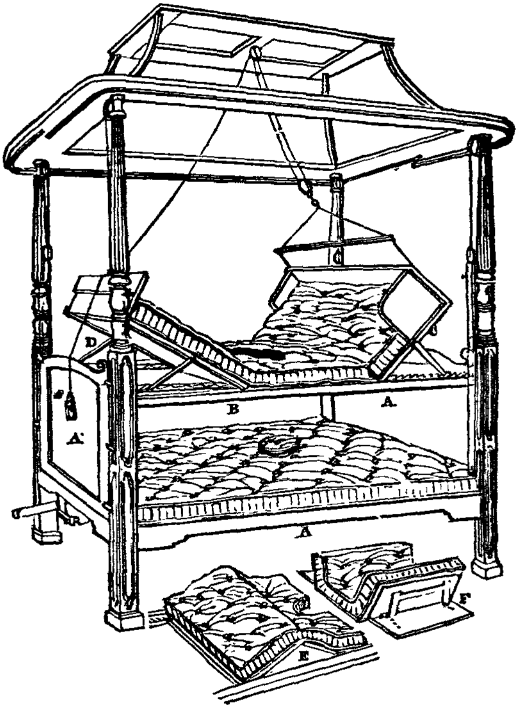
The subjoined figures represent one of the girders employed at Messrs. Nicholson's distillery, to support a liquor back containing 19000 gallons, which, when full, weighs nearly 100 tons. *Fig.* 1 is the elevation of the girder, with one of the flitches removed. *Fig.* 2 a plan of the truss. *a a a Fig.* 1 are three strong plates of cast iron, forming a sort of arch, of which the centre piece may be considered the key-stone, and *b b* cast iron plates, resting on the wall, as the abutments. *c c* cast iron blocks, in which the upper ends of the two side plates *a a*, and the ends of the middle plate are lodged; *d d* blocks of cast iron, which are screwed up against the under side of the girder, by nuts on the end of the screw-bolts passing through the blocks *c c*. *e* is one of two wrought-iron tie bars, passing through the blocks *d d* and *b b*, and secured by nuts at the ends *e*, and which ends, as a further security, are chained. The blocks *b b* have protuberances *f f* which are let into the bearing timbers *g* on the walls *h*. The ends *f b* of the blocks incline outwards about 10 degrees, on which account the flitches of the girder cannot slip down, but must press at the angle *b*, as must also the points between *b f* of the plates *a a*, when the weight presses down the queens by the part of the girder bearing on their shoulder or on the blocks *d d*, thus giving the whole weight to the bars *e* in the direction of their length, just as if the weight were suspended vertically from those bars, or nearly so, the girder being merely a rest for the base of the back. *Fig.* 3 is the end, with the girder trussed on; 4 is the end view of the blocks *d d*, through which the tie bars pass; 5 a section of the inner part of the end block, when trussed; 6 is one of the iron braces which saddle over the flitches, to keep them to at top; and 7 is one of the pieces of oak which fit into the

apertures between the flitches to preserve the bearing. The bars *e* are $2\frac{1}{8}$ inches in diameter, or upwards of $3\frac{1}{2}$ inches area.

We shall conclude this article with a description of a trussed girder proposed by Mr. Gutteridge, and which we insert rather for the novelty of the contrivance, than for any great merit which we can discover in it. *a* is a beam of wood or girder to be trussed, lodging on the walls *h*. *b g b* a wrought iron plate or bar lying on the beam, and attached to iron levers *b c d* by pivots at *b*. These levers are attached to the ends of the beam by iron plates *i*, which are fulcra, *c* being the centre. To the lower extremity or pivots of the arm *c d* is attached a bar of iron *l* at each end, and these are connected by pivots at *e f* to a similar bar *m*, and are kept below the beam by cast iron blocks *k*. The object of this construction is to cause any weight laid upon the beam at *g* to counteract its own tendency to bend the beam, by its increasing the tension of the suspension rods *l m l*, which would cause the blocks *k k* to rise; but the weight of any load is made to increase the tension of the tie-bar by much simpler means in some of the trusses previously described, as in Smart's bow and string rafter, or in the girders at Mr. Nicholson's distillery.



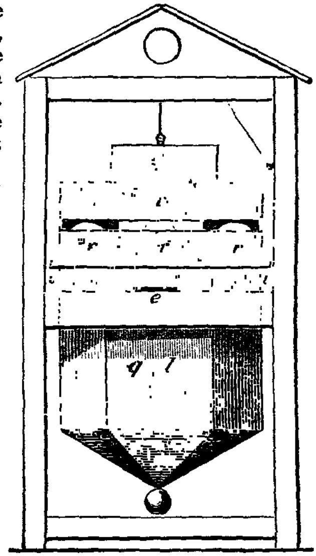
BEDSTEAD. The forms of bedsteads are so numerous, and at the same time, so well known, as to render description at once tedious and unnecessary; we shall, therefore, merely notice a bedstead designed especially for the use of invalids. It is the invention of Mr. Rawlins, of Pentonville, and is named by him the Patent Invalid Bedstead. In the engraving in the next page, which is a perspective representation of this invention, A represents the bedstead; B, swing frame, showing the head and foot frames raised; C, rising head frame; D, rising foot frame; E in the figures underneath shows the elevation of the knee-joint; F, folding side frame. The patient lies on the mattress on the swing-frame, which may rest on the mattress beneath; or, if desirable to be softer, on a bed; and, for the convenience of performing the offices of nature with cleanliness and comfort, the swing-frame is raised up by turning the handles at the head and foot of the bedstead (one, or both, as the occasion may require), so as to admit a bed-pan to be placed beneath a circular hole in the mattress (the cushion which fastens in underneath with a buckle and strap having been previously removed). By raising the swing frame higher, the bed beneath can be shaken up without inconvenience to the patient. In asthmatic and other complaints, where a difficulty of breathing is experienced, the rising head frame may be elevated so as to give the utmost relief the nature of the disorder will admit of. As persons long confined to bed grow weary of lying in one position, a change may be readily obtained by the aid of the attendants, and, in some cases without it. If, for example, it is wished to raise the feet, the attendant raises the rising foot frame by the hand hole in the foot board, and the swing bracket fixed beneath drops into the racks cut on each side of the swing frame, and supports it at the desired elevation; again, if the knees require to be raised, the frame is raised as shown in the figure E, the ends of the frame dropping into the rack before-mentioned; if it is wished to raise and support the body on one side, the folding frame being introduced between the mattress and the swing frame, and the upper leaf of it raised, the patient is quietly turned on his side, and supported in that position by the bracket dropping into the racks cut in the lower leaf as shown in the figure F; in short, the apparatus may be arranged to suit any position which may be desired; and for the accommodation it affords to the invalid, and for the facility with which the



requisite changes are effected, we think this apparatus superior to any invention of the kind which has come under our notice.

BEEHIVE. An artificial habitation for bees, usually constructed of straw. This description of hive is so well known, that we shall only remark upon one or two essential points. First, care should be taken to have the hive made of clean and good straw, and of suitable thickness; and, secondly, it should be well sheltered from cold winds, and rains, for if once the wet penetrates the hives, it affects the combs, and the bees getting a distaste for their home, will work slowly, and often desert it altogether. The culture of bees has, for some years past, been an object of much attention in this country, and numerous improvements have taken place in the construction of the hives, by which the cruel practice of destroying the bees to obtain their honey is obviated, and the produce is very considerably increased by the management of the hives and their inmates. Amongst those who have turned their attention to this subject, Mr. Mott, of Moulton Chapel, Lincolnshire, stands distinguished for the improvements he has introduced in the structure of beehives, and the management of the bees. The most essential part of his plan consists in regulating the heat of the hives by means of ventilation, so as to prevent the swarming of the bees; at the same time obliging them to exchange a hive filled with honey for an empty one placed by the side of it. The cut represents an elevation of one of the forms of hives adopted by Mr. Mott, inclosed in a frame like that of a watchman's box, but surrounded by trellis-work (not shown) instead of close boards. The lower portion *q l* being the warmest, is the apartment for the queen and the larvæ. The entrance for the bees is at a narrow hole at the back of the hive, as at *e*, near to the ventilators *v v*, which are tin tubes open on the outside of the hive, and perforated internally with minute holes (to

prevent the bees from passing through) projecting horizontally towards the centre of the hive; above there is a floor, with large apertures, shown by the dots, which are covered by the receptacles for the honey *r r r r*, into which the bees, therefore, enter from beneath. The compartment of the hive where these vessels are placed, is made to open and shut as a box, the lid of which is shown as opened an inch or two, and so retained by the cord and pulley.



BEER. A fermented liquor, which is most commonly prepared from malted barley, although it is sometimes made from other kinds of grain, either raw, or malted, as wheat, maize, millet; also from sugar and molasses; and, recently, from mangel wurzel; in fact, it may be obtained from most vegetable substances which contain saccharine matter, uncombined with any acid. Beer, or a fermented liquor prepared from grain, was known to the ancient Egyptians, with whom, indeed, the art of preparing it is supposed to have had its rise. Beer was also in use with the ancient Gauls, Saxons, Britons, and other nations of the north and west of Europe; and is, at the present, a common beverage in most countries where grain is plentiful, and where the grape does not flourish. Park and Lander both mention it as extensively used in various parts of the interior of Africa. It does not appear that either the Egyptians, or any of the nations of antiquity, used hops, or any similar substance, with their worts, on which account their beer would not be well adapted for keeping. This improvement in the art of brewing was introduced in England about the beginning of the sixteenth century; at the outset the practice encountered some prejudice; and, in an old act of parliament, hops are denounced as a poisonous weed. In England, two distinct sorts of beer are known, called *ale*, and porter, or beer, and of each sort there are numerous varieties. Although the difference in the flavour of ale and of porter is sufficiently marked, it is difficult to say in what way it is produced; that it is not altogether owing to pale malt being used for brewing ale, as some assert, is clear from the fact that, in many parts of the country, ale is brewed from brown malt; neither is it owing to a larger quantity of hops being used in making porter, for the pale ale, which is exported in large quantities from this country to India, contains a larger proportion of hops than the porter exported to the same place; neither will a difference in the proportions of the malt to the water account for it, since some ales are stronger, and others weaker, than porter. It is also singular that, although capital ale may be brewed in private families, few persons but the London brewers, who have very large establishments, can make good porter. Although the various causes we have just noticed may have some effect, we imagine that the difference is principally caused by the addition of certain ingredients to the worts during the process of fermentation. This practice, although not openly avowed, is, nevertheless, well known to be pretty general; and it is also certain that some of these additional ingredients are of a very noxious and unwholesome description. For the process of making beer, see BREWING.

BEER MACHINE. An ingenious contrivance, of comparatively recent introduction, for drawing beer from different casks, situated in an apartment or cellar beneath, without descending for that purpose; by which means much trouble and great waste of liquor is avoided. The machine consists of three or four small lift and force pumps, firmly bedded in two blocks of wood, and

inclosed in a handsome mahogany case. To the lower end of each pump is attached a suction pipe, which is inserted in a cask of beer, (each pump being employed to draw a particular quality of beer,) and from the upper end of the pump proceeds a pipe connected to a nozzle in front of the case of the machine. The piston rod passes through a small stuffing box on the cover of the barrel, and through a guide, by which its parallel movement is secured; and it is connected by slings to a bent lever, by which it is worked. This lever consists of a short arm, to which the slings are attached, and stands at an angle of about 130° with the long arm or handle, which works through a slit in the semicircular head of the case. A small cistern of white metal is fitted to the case beneath the nozzles, and from it a pipe conveys the drippings to the waste-butt.

BELL. A hollow vessel of metal, formed to produce a sound by the act of striking it. The principal uses to which bells are applied, are to sound the hours, and to summon persons from a distance. The forms of bells vary considerably, some being segments of spheres, others truncated cones, but the most common form is that in which the sides diminish in a curve line from the base to the upper edge, the crown being slightly convex. The use of bells is very ancient and extensive, as they were to be found amongst Jews, Greeks, Romans, Christians, and Heathens, variously employed. Their first application to ecclesiastical purposes is said to have been about the year 400, and in the city of Nola. In Britain, bells were used in churches before the close of the seventh century. Abroad are bells of dimensions greatly exceeding any to be met with in this country. At Rouen, in Normandy, was a bell said to weigh 36,000 lbs. At Erfurth is one weighing 28,200 lbs.; its periphery is 14½ ells, and its height, 4⅔ ells. In the church of St. Ivan, at Moscow, is a bell weighing 127,836 lbs.; but the largest bell in the known world, is the unsuspended bell in the Kremlin of that city. It is computed to weigh 443,772 lbs. In England, the largest is "Great Tom," of Christ Church, Oxford, weighing 17,000 lbs.; the great bell of Lincoln weighs 9,894, and that of St. Paul's, 8,400 lbs.

BELL, DIVING. See DIVING APPARATUS.

BELLOWS. An instrument for directing a current of air against burning fuel, to increase the combustion. The ordinary bellows, for domestic use, are so well known, as scarcely to require description, consisting merely of two flat boards, united by a sort of hinge joint, and having a piece of leather, (broad in the middle, and narrow at the two ends,) nailed round the sides of the boards, to allow them to separate or move through a small angle. In the lower board is a hole, through which the air enters, upon raising the upper board; but being prevented from escaping on pressing down the upper, by a leather flap valve, which covers the hole, it is forced through a pipe or nozzle fitted at the junction of the boards, and having a small valve behind it, opening outwards. For bellows for manufacturing purposes, see BLOWING MACHINES.

BEN, OIL OF. This is obtained from the ben nut by simple pressure. It is remarkable for its not growing rancid in keeping, or at least not until it has stood for a number of years; and on this account it is used in extracting the aromatic principle of such odoriferous flowers as yield little or no essential oil in distillation.

BENZOIC ACID. An acid commonly obtained from benzoin, although it exists in various substances, as vegetable balsams, cinnamon, the urine of horses, cows, &c. It is usually procured from benzoin, either by sublimation, or by digesting the powdered benzoin in lime water, and afterwards separating the lime by the addition of muriatic acid. It crystallizes in fine silky filaments, of a white and shining appearance, and of a spec. grav. of 0.667; it is soluble in sulphuric and nitric acids, alcohol, oils, and tallow, but is only slightly soluble in water. It unites easily with the earthy and alkaline bases.

BENZOIN, or BENJAMIN. A resin which exudes from incisions made in a certain species of tree growing in the East Indies, particularly Siam, and the island of Sumatra. This resin is moderately hard and brittle, and yields an agreeable smell when rubbed or warmed. It is totally soluble in alcohol, from which, like other resins, it may be precipitated by the addition of water.

BERYL. A precious mineral, commonly green, but of various shades, passing into honey yellow and sky blue. Its spec. grav. is 2.7. It differs from emerald in hardness and colour. It has been called aqua marine, and greenish yellow emerald. It is electric by friction, and not by heat.

BEVIL. An instrument for measuring and transferring the angle formed by two surfaces; it consists merely of two straight legs, turning upon a common centre, and is used by the two limbs coinciding with the surfaces where an angle is to be ascertained. The annexed engraving represents an instrument by which curved surfaces may be gauged, or the curve transferred to any kind

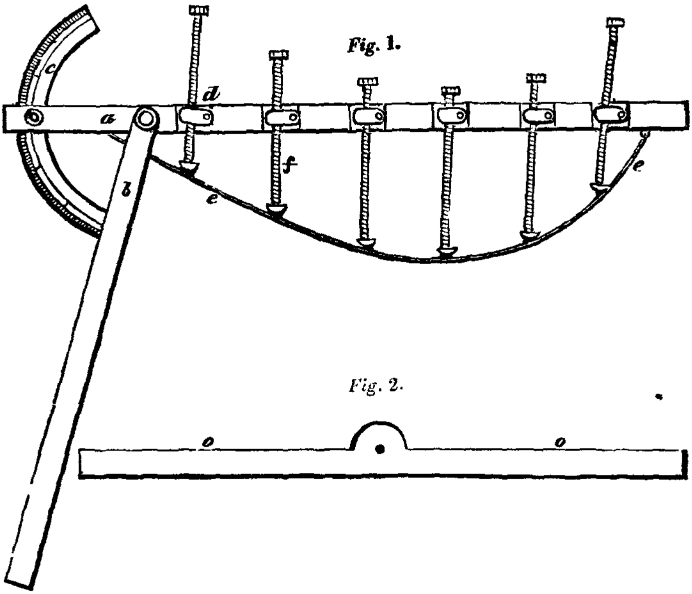


Fig. 1.

Fig. 2.

of work, or to paper. *a* and *b Fig.* 1, are two rulers connected together by a circular joint; *c* is an arch of brass fixed to *b*, and sliding through a mortise or slit in *a*, to which it is fastened at pleasure, at any required angle, by means of the screw in *a* pressing upon it. The rule *a* has six or more square mortises made through it, (shewn in section in the drawing,) in which are placed as many nuts moving on pivots; each of these nuts is tapped to receive a long screw (as at *f*,) working within them; and each of the long screws is fixed at one end to a flexible steel blade, *e e*, by means of a kind of swivel joint which admits of the screw turning round in it without advancing, and allows it to press either direct or aslant. Consequently, when the opposite ends of the screws are turned by the thumb and forefinger, the steel blade is pressed out so as to adapt itself to any given curve; and being thereby fixed in the same position, the curved line can be transferred therefrom to any kind of work, or on to paper. *Fig.* 2 shews a contrivance for drawing the radii of wheels with great expedition; it is formed of a slip of thin brass, and the central hole must be in the line *o o;* if now a needle point passing through the hole be inserted in the centre of the circle representing the wheel, the radii may be drawn with great facility and exactness along either of the lines *o o*, to the different points or degrees previously marked upon the circumference.

BINNACLE. A small case, in which is placed the compass-box. It is fixed to the deck in front of the steersman, and is furnished with glazed apertures to admit light upon the compass, and exclude rain in the day, and at night is lighted up by a lamp placed within it. These lamps are variously constructed;

sometimes a hole is cut through the deck immediately below the compass, and a lamp is so placed as to give light to the compass and the cabin also; in this case the card of the compass is formed of a semi-transparent material.

BINOCULAR TELESCOPE, is a telescope to which both eyes may be applied at once, and consequently, the same object observed at the same time with both. It consists of two tubes, with two sets of glasses, of the same power, and adjusted to the same axis, which has been said to exhibit objects larger and more distinct than a single or monocular glass. There are also microscopes of the same construction, but they are very seldom used.

BIRD-LIME. The best bird-lime is made of the middle bark of the holly, boiled seven or eight hours in water, and, when soft, it is laid in pits in the ground, and covered with stones, and left to ferment till it is reduced to a kind of mucilage. It is afterwards kneaded till it is freed from extraneous matter, and then washed in a running stream till no impurities appear. In this state it is left four or five days in earthen vessels to ferment and purify itself, when it is fit for use. It may likewise be obtained from the misletoe, young shoots of elder, and other vegetable substances. It is sometimes adulterated with turpentine, oil, vinegar, and other matters. Good bird-lime is of a greenish colour, and sour flavour; gluey, stringy, and tenacious; and, in smell, resembling linseed oil.

BISCUIT. A species of unleavened bread. There are several sorts of biscuit, each having a distinguishing name; but the most important, from its very great consumption, is the sea biscuit, destined for the use of shipping. A new baking establishment having been recently formed at the Royal Clarence Victualling Establishment, at Weevil, near Portsmouth, upon a scale of magnitude nearly sufficient to supply the whole royal navy with biscuit, and that of a very superior description, the following account, taken from the *United Service Journal* will, we trust, be acceptable to our readers. "It having been discovered that the flour supplied to government by contract had, in many instances, been most shamefully adulterated, the corn is ground at mills comprised within the establishment, and by which means the introduction of improper ingredients is prevented, and precisely the proportion of bran which is requisite in the composition of good sea-biscuit is retained, and no more. The flour-mill is furnished with 10 pair of stones, by which 40 bushels of flour may be ground and dressed, ready for baking, in an hour. The baking establishment consists of 9 ovens, each 13 feet long by 11 feet wide, and 17½ inches in height. These are each heated by separate furnaces, so constructed, that a blast of hot air and fire sweeps through them, and gives to the interior the requisite dose of heat in an incredibly short space of time. The first operation in making the biscuits consists in mixing the flour, or rather *meal* and water; 13 gallons of water are first introduced into a trough, and then a sack of the meal, weighing 280 lbs. When the whole has been poured in by a channel communicating with an upper room, a bell rings, and the trough is closed. An apparatus, consisting of two sets of what are called knives, each set ten in number, are then made to revolve amongst the flour and water by means of machinery. This mixing lasts one minute and a half, during which time the double set of knives, or stirrers, make twenty-six revolutions. The next process is to cast the lumps of dough under what are called the *breaking-rollers*—huge cylinders of iron weighing 14 cwt. each, and moved horizontally by the machinery along stout tables. The dough is thus formed into large rude masses, 6 feet long, by 3 feet broad, and several inches thick. At this stage of the business the kneading is still very imperfect, and traces of dry flour may still be detected. These great masses of dough are now drawn out, and cut into a number of smaller masses about a foot and a half long by a foot wide, and again thrust under the rollers, which is repeated until the mixture is so complete that not the slightest trace of any inequality is discoverable in any part of the mass. It should have been stated that two workmen stand one at each side of the rollers, and as the dough is flattened out, they fold it up, or double one part upon another, so that the roller, at its next passage, squeezes these parts together, and forces them to mix. The dough is next cut into small portions, and being placed upon large flat boards, is, by the agency of

machinery, conveyed from the centre to the extremity of the baking-room. Here it is received by a workman, who places it under what is called the *sheet-roller*, but which, for size, colour, and thickness, more nearly resembles a blanket. The kneading is thus complete, and the dough only requires to be cut into biscuits before it is committed to the oven. The cutting is effected by what is called the cutting-plate, consisting of a net-work of 52 sharp edged hexagonal frames, each as large as a biscuit. This frame is moved slowly up and down by machinery, and the workman watching his opportunity, slides under it the above described blanket of dough, which is about the size of the leaf of a dining-table; and the cutting-frame, in its descent, indents the sheet, but does not actually cut it through, but leaves sufficient substance to enable the workman at the mouth of the oven to jerk the whole mass of biscuits, unbroken, into the oven. The dough is prevented sticking to the cutting-frame, by the following ingenious device; between each of the cutter frames is a small flat open frame, movable up and down, and loaded with an iron ball, weighing several ounces. When the great frame comes down upon the dough, and cuts out 52 biscuits, each of these minor frames yield to the pressure, and are raised up; but as soon as the great frame rises, the weight of the balls acting upon the little frames thrusts the whole blanket off, and allows the workman to pull it out. One quarter of an hour is sufficient to bake the biscuit, which is afterwards placed for three days in a drying room, heated to 85°, or 90°, which completes the process." The following statement of the performance of the machinery is taken from actual experiment: in 116 days, during 68 of which the work was continued for only 7½ hours, and during 48, for only 5¾ hours each day, in all 769 working hours, equal to 77 days of 10 hours each, the following quantity of biscuit was baked in the 9 ovens; viz. 12,307 cwt.=1,378,400 lbs. The wages of the men employed in baking this quantity amounted to 273*l.* 10*s.* 9¼*d.*; if it had been made by hand the wages would have been 933*l.* 5*s.* 10*d* ; saving in the wages of labour, 659*l.* 7*s.* 0½*d.* In this is not included any part of the interest of the sum laid out upon the machine, or expended in keeping it in order. But in a very few years, at such an immense rate of saving, the cost of the engine and other machinery would be repaid. This admirable apparatus is the invention of T. T. Grant, Esq. Storekeeper of the Royal Clarence Victualling Establishment, who, we believe, has been rewarded by a grant of 2,000*l.* from Government.

BISMUTH. A brittle metal, of a yellowish white colour; it is somewhat harder than lead, and melts at 480° Fahr. Urged by a strong heat in a close vessel, it sublimes entire, and crystallizes very distinctly when gradually cooled. Bismuth unites with most metallic substances, and renders them, in general, more fusible. 8 parts of bismuth, 5 of lead, and 3 of tin, form what is called fusible metal, which melts in boiling water. Bismuth is used in the composition of pewter, in the fabrication of printers' types, and, combined with lead and tin, forms plumbers' solder.

BISTOURY, in Surgery, an instrument for making incisions, of which there are different kinds, some straight and fixed in a handle like a knife; some are of the form of a lance, while others are crooked, with the sharp edge on the inside.

BISTRE. A brown pigment, consisting of the finest part of wood-soot, pulverized, and passed through a fine sieve, then mixed with a little gum-water, made into cakes, and baked. It is a fine transparent colour, and has much the same effect in water-painting, where alone it is used, as brown pink in oil. The best is prepared from dry beech wood, by grinding it with water into a smooth paste, then diluting it with more water. After the grosser liquor has subsided, the liquor is poured off, and left to settle for a few days; the fine matter that remains is the bistre.

BIT. The iron which is put into a horse's mouth, and to which the bridle is attached. There are various descriptions of bits, but they may all be ranged under two heads, the snaffle and the curb; in the snaffle, the bit is formed slightly curved, and frequently jointed in the middle, and the bridle, or rein, is attached to rings in the extremities of the bit. Curb bits are generally formed

with a small semicircular bend in the centre of the mouth-piece, and with arms or cheek-pieces formed at the ends of the mouth-piece. To the upper part of the cheek-pieces is hooked a chain passing under the lower jaw of the bone, and to the lower end of the cheek-pieces is attached the rein, by pulling which, the upper ends of the cheek-piece are thrown forward, and the curb chain pressed forcibly against the lower jaw. Curb bits are very powerful in checking a horse, from the leverage afforded by the cheek-piece, but they tend greatly to injure the mouth, and cause much uneasiness to the animal. Mr. George Diggles, of Westminster, took out a patent, some years back, which, for ordinary riding or driving, is attended with no more injury or irritation to the horse's mouth than the ordinary snaffle, but which, when occasion requires, instantly acts as a very powerful curb. This effect is obtained by means of a sliding piece, with a ring attached to each cheek of the bit, to which ring the rein or bridle is connected in the usual way; and when it is found necessary to exert a considerable force in curbing the horse, the pulling of the rein will draw the slider towards the bottom of the cheek, thus lengthening the lever so considerably that the horse is arrested by an irresistible power. The annexed, *Fig.* 1, represents a side view of the improved bit, applied to a horse's head, and in the ordinary position, when riding or driving; the dotted lines show the position of the parts when the rein is pulled with considerable force. *Fig.* 2 gives a

Fig 2.

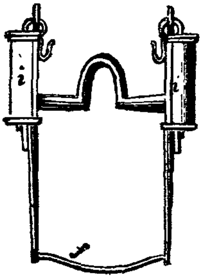
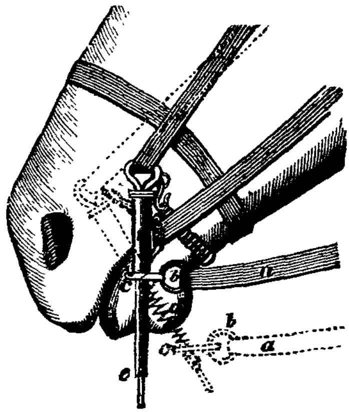


Fig. 1.



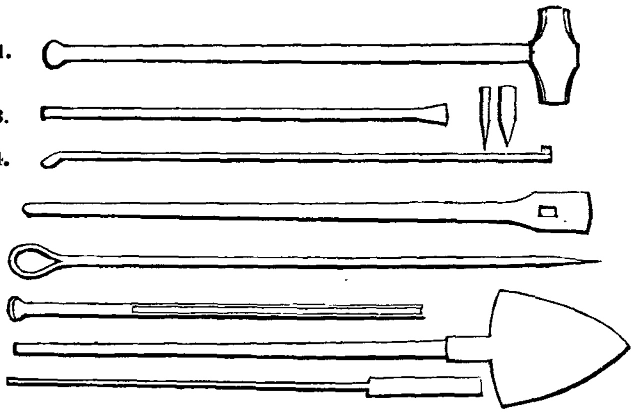
front view of the improved bit. *a* is the riding or driving rein attached to the ring *b*, which instead of being fixed to some particular part of the bit, as in the ordinary bit, is attached to a sliding piece *c*. A convoluted spring *d* acts upon this sliding piece, and keeps it and the ring *b* up to that part of the cheek which is near the mouth-piece, *Fig.* 2, where the leverage being small, the riding or driving rein will act in the ordinary manner; but when it becomes necessary to exert an extraordinary power upon the horse's mouth, the rein *a* is forcibly pulled back, by which the cheek of the bit is moved out of its perpendicular position, and the sliding piece *e*, with the ring, slides downwards towards the lower part of the cheek, as shewn by the dotted lines. To prevent the ring and slider from being drawn too low, a stop is placed on the bit at *e* for a riding bit, but for a driving bit, the bar at the bottom of the bit, as seen at *f*, answers the purpose. When the tension of the rein is relaxed, the elastic force of the spring draws up the sliding piece *c*, with the ring *b*, and the rein *a*, to its ordinary place, as represented in *Fig* 1. The cases *i i*, which contain the springs, are made to slide up and down in grooves, formed on opposite sides of the cheeks, for the convenience of oiling, exchanging, cleaning, or repairing the springs

BITTERN. The mother water which remains after the crystallization of common salt in sea water, or in the water of salt springs. It abounds with sulphate and muriate of magnesia, to which its bitterness is owing.

BITUMEN. A term including a considerable range of mineral substances, which burn with flame in the open air. They vary, in consistency, from a thin liquid to a solid; but the solids are for the most part liquifiable at a moderate heat. It also forms a component part of various substances, as jet, amber, and all the varieties of pit-coal.

BLANKET. A warm, woolly sort of stuff, light and loosely woven, used in bedding. The manufacture is chiefly confined to Witney, in Oxfordshire, where it is the principal article of trade. The excellent quality of Witney blankets has been attributed to the abstersive nitrous water of the river Windrush, wherewith they are scoured. Blankets are made of felt wool, that is, wool from sheep skins, which they divide into several sorts. Of the head wool, and bay wool, they make blankets of twelve, eleven, and ten quarters broad; of the ordinary and middle sort, blankets of eight and seven quarters broad; of the best tail wool, blankets of six quarters broad, commonly called cuts, serving for seamen's hammocks.

BLASTING. An operation resorted to in mines and quarries for the purpose of detaching large masses of earth or stones. The implements employed, (which are few and simple,) are shown in the engraving. *Fig.* 1. The sledge



hammer, or mallet. *Fig.* 2. The borer, or chisel. *Fig.* 3. The wedges. *Fig.* 4. The scraper. *Fig.* 5. The claying bar. *Fig.* 6. The needle. *Fig.* 7. The tamping bar. *Fig.* 8. The shovel. *Fig.* 9. The fusee inserted in the charge. To perform the operation of blasting, two men only are requisite. The miner's judgment directs him to the fittest place for the charge, and a hole is bored or cut in the rock, in the following manner, to receive it. The borer, or chisel, *Fig.* 2, is held by one man, whilst the other man strikes it with the hammer or mallet; the man holding the chisel turning it at every blow, so as to cross the previous cut, by which means the stone is chipped away by degrees. The boring, or cutting, is occasionally suspended to clear out the hole, which is done by the scraper, *Fig.* 4. When the perforation is of the required depth, (which varies from one to three feet, the diameter being about an inch and a half,) if the hole be wet, some tough dry clay is introduced, and the claying bar, *Fig.* 5, is driven in with great violence, by which means the clay is forced into all the crevices, absorbing the moisture, and preventing the entrance of more; on withdrawing the claying-bar, the hole is left dry, and of a smooth uniform surface, which adapts it for receiving the charge. This consists of gunpowder alone, or mixed with some quicklime, (which it is said increases the force of the explosion); it is inclosed in paper as a common cartridge, to fit the bore; but in very wet situa-

tions, a tin case is sometimes used to contain it. The charge being now introduced, and thrust to the bottom of the hole by means of a thin tapering copper rod called the needle, *Fig.* 6, which is also driven down with the charge. The next operation is to exclude as much of the air as possible, by reducing the size of the vent; for this purpose, the tamping bar, *Fig.* 7, is employed in ramming round the needle some yielding yet compact substance, so that when the needle is withdrawn, a very small vent or touch-hole remains. Into this perforation is dropped a fusee, or rush, charged with powder, on the top of which is fixed a "snuft," as it is called, or some other contrivance, so adjusted as to burn a sufficient time to permit the man who fires it to retreat to a proper distance. Previous to firing, it is usual to give notice to all persons in the immediate neighbourhood, by blowing a horn or ringing a bell, that they may have the opportunity of retiring to some place of security.

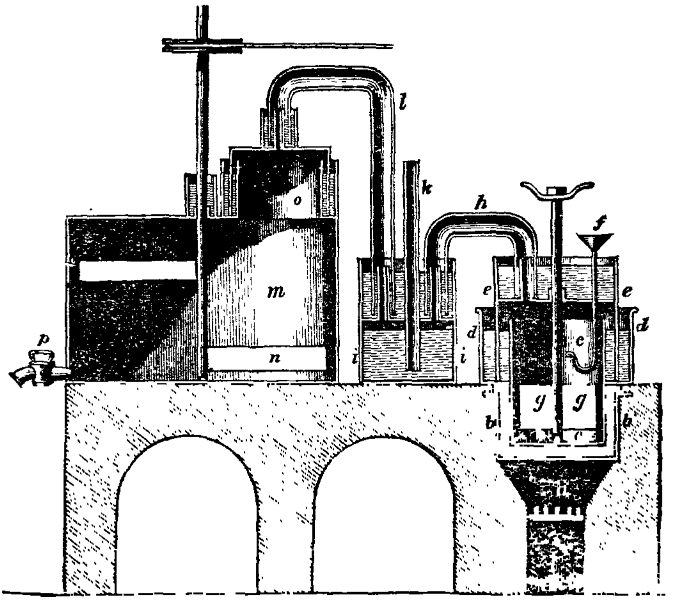
BLEACHING. The art of freeing cloths and various other substances from their natural brown or dusky tinge, and rendering them perfectly white. The most ancient, and at one time the only known, method of bleaching linen, or cotton cloths, consists in frequently wetting them, and exposing them upon the grass to the rays of the sun; the powerful action of which in the destruction of colours is well known. This process, which is distinguished by the term of "Grass bleaching," has, however, been nearly superseded by another termed "Gas, or Chemical bleaching," founded upon one of those brilliant and useful discoveries, by which modern chemical science has so honourably distinguished itself, and rendered such service to the arts of life. Before proceeding to describe the new, (and now the ordinary process,) we shall give a brief description of the method of grass bleaching, as, although not generally practised, it is still in use in some parts. The details of the process vary of course with the nature of the goods; but the following is the process for bleaching flax-yarn, which constitutes an important branch of business. The first operation, called *steeping*, consists in immersing the brown yarn in hot water, or in allowing it to macerate in cold water, or in alkaline ley. This occasions a kind of fermentation, which loosens the saliva employed in spinning the yarn, and so far separates the other impurities attached to it, that the whole may be easily removed by washing in river or spring water. The next operation is that of *bucking*, or boiling in an alkaline lye, after which the skeins are exposed on the grass, for two or three weeks, which latter operation is called *crofting*. These alternate operations of bucking, washing, and crofting, are generally repeated four or five times, each time lessening the strength of the alkaline solution in which the bucking was performed. The next process is that of *scouring*, which, as more anciently practised, consisted in soaking the yarn in milk, which had become acidulous by age, which was usually employed, for the first time, immediately after the fourth or fifth bucking. In this liquor, which was technically called the first sour, the goods generally lay for three weeks, or until such time as the scum began to crack and subside, when they were usually taken out and submitted to a repetition of the processes already described. Thus, whenever the goods had been once soured, the operations of bucking, washing, scouring, and crofting, were repeated in regular rotation, until the yarn came to a good colour, and was esteemed perfectly clear. These tedious operations have been much shortened by substituting very dilute sulphuric acid for the sour milk. This improvement (suggested by Dr. Home,) so much accelerated the process, that one souring by sulphuric acid may be performed in from 12 to 24 hours; whilst every souring by the milk process required from two to six weeks; and the whole process may by this means be completed in four months, which before required seven or eight months. We shall now proceed to give a slight history and description of the new system of bleaching, founded upon the property which chlorine possesses, of rapidly destroying vegetable colours. By this system, (which furnishes one of the most beautiful illustrations of the immense benefits which science may render to the useful arts,) the practice of bleaching is conducted with a degree of precision before unknown, and with the most surprising expedition. For the discovery of chlorine, we are indebted to Scheele, who, in the year 1774, first formed it by art, and afterwards ascertained its

powers in destroying vegetable colours. But the first person who made experiments upon this gas, with a view to its application in the arts, was Mr. Berthollet, who, in the *Journal de Physique*, for June, 1785, and again in the number for August, 1786, explained the nature of its action on vegetable colours, and suggested how it might be applied with advantage to the process of bleaching. The subject soon attracted the attention of various scientific persons and enterprising manufacturers, and numerous establishments were formed, in which the process of Berthollet (modified by subsequent discoveries,) was adopted. Amongst the first to introduce and perfect the new process in this country, were Professor Copland, the celebrated Watt, and Mr. Henry, of Manchester. Mr. Watt, so early as 1787, had introduced it in the bleaching field of Mr. Macgregor, at Glasgow; and in his first attempt, he bleached 500 pieces of cloth; and Mr. Henry, in the year 1788, published an account of the process, as practised by himself, which account comprehends every thing at this time known respecting the use of chlorine gas in bleaching, excepting the condensation of the gas, by means of lime. At the first introduction of the new process, the chlorine was employed in the state of gas, but this method was found to be attended with many inconveniences; the fumes occasioning considerable annoyance to the workmen, and the texture of the cloth being frequently injured by the too great energy of the gas. It was also found extremely difficult to expose all the surfaces equally to its action, without which no perfect bleaching can ever be effected. The first remedy for these inconveniences consisted in condensing the gas in water, and subsequently in a solution of potash, which imbibed the gas more readily than water alone, and formed a more concentrated liquor. This latter process was invented by some manufacturers at Javelle, whence the liquid was named—“ *Liquer de Javelle.*”

In the year 1798, Mr. Tennant, of Glasgow, took out a patent for a new bleaching liquor, which consisted of a solution of chlorine of lime, instead of oxymuriate of potash, which, besides being equally efficacious with the former for general purposes, has the advantage of being much cheaper. It is not, however, applicable where cottons are subsequently to be dyed with madder: for bleaching these, the oxymuriates of potash or soda must be employed. The peculiar advantages of combining chlorine with lime, or the alkalies, consists in the circumstance that the saline solution gives out the gas gradually to the goods which require bleaching, but does not part with it to the atmosphere with the same facility. In consequence of this, the operation of bleaching is now not injurious, nor even very disagreeable, to the workmen; whereas, in the former process, when the gas was merely received into water, it was so freely given out again that no man could long endure to work in it, or even, for any considerable time, to superintend the operations. This advantage of the new process more than compensates for the diminution of the bleaching power of chlorine, which results from the aforesaid combinations. Mr. Tennant's patent for the liquid chloride of lime was afterwards set aside; but he subsequently obtained a patent for combining chlorine with lime in the dry state. This is a most valuable improvement, the dry chloride being less liable to decomposition than the liquid, and being so much more portable, the smaller manufacturers find it more advantageous to purchase the article of those whose business it is to prepare it, than to establish works for the preparation of the article themselves. The following is the process as practised in bleaching linen, or cotton cloth, or yarn. The same methods are followed as far as the fourth or fifth bucking, as described in the process of grass bleaching, only good washing is substituted for crofting. The goods are then immersed in a solution of chloride of lime, or of the chlorides of potash or soda, and are then well washed, by machinery, in pure water. They are then taken to the souring vessels, containing a portion of very dilute sulphuric acid, and when taken out of these vessels, are again well washed in water; and, lastly, they are submitted once more to the alkaline process already described. Linen goods require, at least, three immersions in the solution of chloride of lime, followed by an equal number of alternate immersions in the sours and in the alkaline solutions, carefully and thoroughly washing them in pure water between each of these processes. Cottons, however,

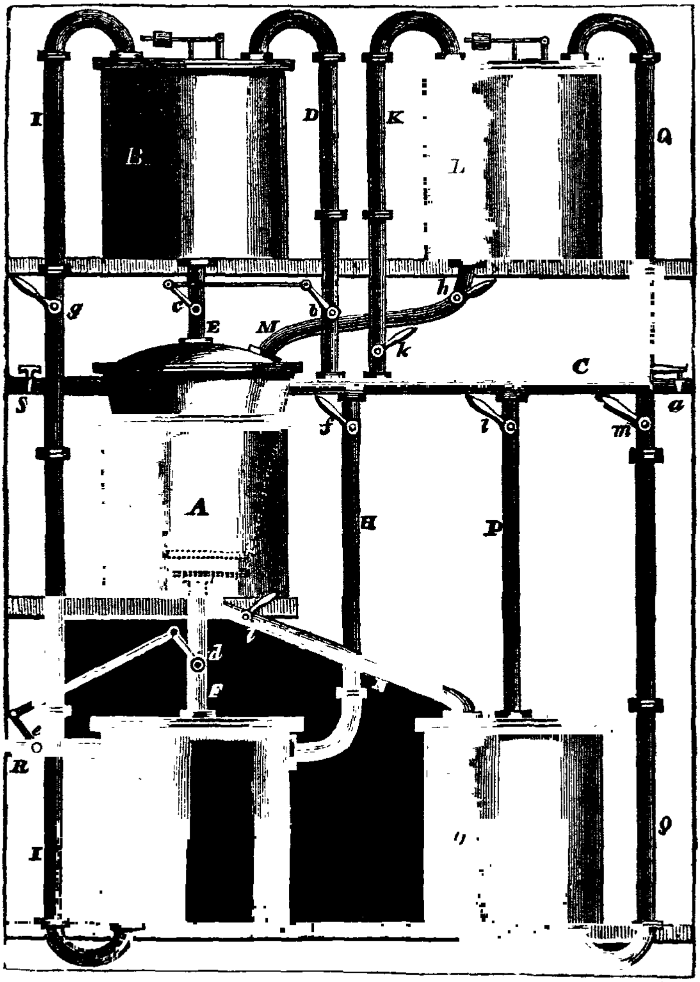
require fewer immersions in the bleaching liquor, which may likewise be more diluted with water for cottons than for linens. By this method of bleaching, linen goods constantly acquire a yellowish tinge; this, however, is so superficial, that mere exposure to the air for a few days generally removes it. The goods are then finished by boiling them for a short time in a diluted solution of pearlash and white soap, which removes the disagreeable odour which would otherwise be attached to articles bleached by this process. Cotton goods do not require crofting, as the yellow tinge, just mentioned, does not appear in them when finished, being removed by the sulphuric acid, although this acid will not remove it from linen goods. But the routine just described, Mr. Parkes (from whose essay on bleaching much of the preceding account is taken,) observes, is not sufficient for bleaching calicoes intended for the best madder work. The following outline of a process adopted by a scientific printer in Scotland, for bleaching calicoes for madder work, or resist work, or for pale blue dipping, was communicated by him to Mr. Parkes, with an assurance that it may be relied on. The goods, after being singed, steeped, and squeezed, by passing between rollers, are boiled four times, ten or twelve hours each time, in a solution of caustic potash of a spec. grav. from 1.0127 to 2.0156, washing them carefully and thoroughly between each boiling. They are then immersed in a solution of the chloride of potash, originally of the strength of 1.00625, and afterwards reduced, with twenty-four times its weight of water, but as the specific gravity alone is not a perfect guide, the bleaching power of the liquid is tested by a solution of indigo of a known strength. In the above preparation, the goods are allowed to remain 12 hours, and are then, by some printers, laid, whilst wet, on the grass, and exposed to the sun and weather for two or three days. From thence they are removed to the sours, made of the spec. grav. of about 1.0254, at the temperature of 110° Fahr.; and after lying five or six hours, are taken to the wheel, and washed. The four boilings in caustic potash, with the washings between each, are then repeated, and the goods, after being again immersed in the diluted chloride of potash, are well washed in pure water, and then rinced in common sours for half an hour. The last process is that of careful washing in clean water, after which they are immediately hung up in the airing sheds to dry gradually. Various articles, besides cloth, such as wax, paper which has become mildewed, &c. are now bleached by means of chlorine, either in the state of gas, or combined with alkalies or alkaline earths. The annexed engraving represents the apparatus employed for the preparation of chloride of potash, or soda, for the use of calico printers. *a* is the furnace for heating the materials which furnish the chlorine; *b* a cast iron vessel containing water, and forming a water bath for the reception of the still; *c* the body of the still made of lead, and the upper part surrounded by a deep cup *d d* formed in one piece with it, and containing a portion of water into which the head of the still descends to the depth of about six inches, thus forming what is termed a water-joint, which prevents the escape of the gas; *e* is the still head descending, as we have just stated, into the water; in the cup *f* is a bent funnel, through which the acid is poured into the still; *g* an agitator for stirring the materials in the still, working through an air-tight aperture; and *h* the eduction pipe, by which the gas passes into *i*, an intermediate vessel, partly filled with water, and designed to arrest any uncombined muriatic acid which may occasionally rise from the still during the process; *k* a safety tube; and *l* the pipe which conveys the gas into *m*, the large receiver made of lead, and charged with the alkaline solution; *n* the agitator for constantly stirring the alkaline solution; this is necessary to promote the absorption of the gas; and, in large works, the agitator is moved by power from a steam-engine; *o* an opening for filling the receiver, occasionally cleaning it out, &c.; *p* discharge cock for drawing off the saturated solution. The junction of all the various pipes and openings are rendered air-tight by water-joints. At the first introduction of the new process, the chlorine was obtained by distilling muriatic acid upon the black oxide of manganese; but it is now procured in a simpler and more economical manner, by mixing together black oxide of manganese, common salt, and diluted sulphuric acid; various proportions are used by

different manufacturers: Mr. Tennant recommends equal weights of salt, oxide, and acid, and a quantity of water equal to the *measure* of acid. Silk and



woollen goods being animal productions, different processes are employed in bleaching them. The colouring principle of silk being resinous, M. Baumé has proposed a process for extracting it by digesting the silk in alcohol acidulated by muriatic acid, but the ordinary method of bleaching silk is the following. The silk being still raw, is inclosed in a linen bag, and boiled in a solution of soap for two or three hours, the bag being frequently turned. It is then taken out and beaten, and next washed in cold water; and, after being slightly wrung, it is a second time put into the boiler filled with cold water, mixed with soap and a little indigo, which gives it that bluish cast commonly observed in white silk. When the silk is taken out of this second water, they wring it hard with a wooden peg to press out all the soap and water; after which they shake it to untwist it, and separate the threads. It is then suspended in a kind of stove constructed for that purpose, in which sulphur is burning, the vapour of which gives the last degree of whiteness to the silk. Woollen cloths are sometimes bleached by simply scouring them with soap and water after the operation of the fulling mills, and sometimes by sulphuric acid gas, which is effected as follows:—The stuffs are first well washed and cleansed in river water, and then put upon poles to dry. When half dry, they are exposed to the vapour of burning sulphur, or sulphurous acid gas, in a very close stove; the gas gradually adhering to the surface of the stuff, renders it beautifully white. An improvement upon this method is to condense the sulphurous acid in water, and immerse the stuffs therein; by which means the acid acts more equally over the whole surface, than when in the state of gas. The gas may also be obtained by digesting sulphuric acid upon chopped straw, saw-dust, or other carbonaceous matter, in a retort, and the gas may be condensed by an apparatus similar to that used for condensing the chlorine gas. High pressure steam has been lately employed instead of chlorine for bleaching cloths. It is said that this method of bleaching has long been practised in the east, but Chaptal is the first writer who recommended it to the European bleacher; and Mr. S. Wright has taken out a patent in this country for an apparatus for washing and bleaching upon this principle,

which apparatus is represented in the annexed engraving. The goods to be bleached are first packed closely into a conical vessel, through which the steam is caused to pass for a while; the steam is then made to force an alkaline solution through the goods, to remove the impurities and colouring matter (which operation is repeated as often as may be necessary); hot water is next impelled through the goods to remove all the alkaline matter; and, lastly, steam of a high pressure is forced through to expel the water, by which the goods



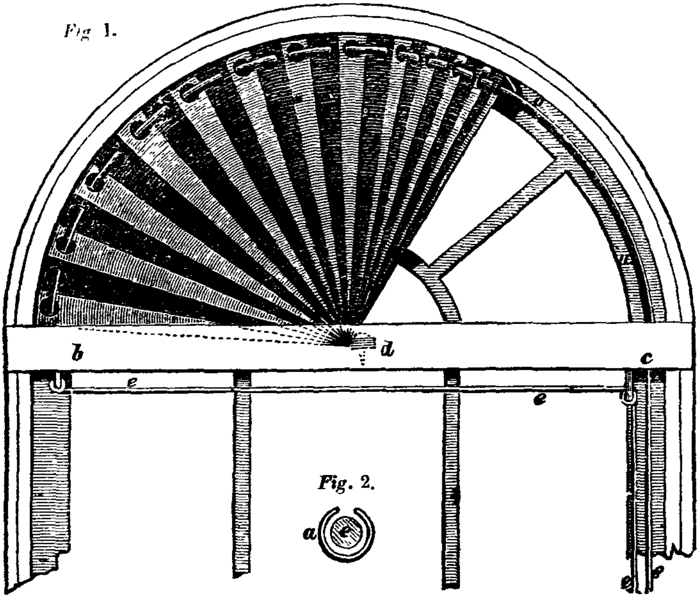
are left in nearly a dry state, and perfectly clean. *a* is a copper vessel, formed as frustrum of a cone, at the lower part of which is a perforated false bottom, or grating, and below this the real bottom, from which a pipe descends. The articles to be operated upon having been previously laid in water and rubbed with soap, are to be closely packed in this vessel, the lid of which is then to be screwed down and rendered steam-tight at the junction. In the diagram this vessel is represented enclosed in a jacket, to prevent the radiation of heat;

B is a vessel (also of copper, as well as the other vessels and tubes represented), containing soap and water, or the usual alkaline solutions of pearl-ash, soda, &c.; C is a pipe leading from a steam boiler, through which is introduced steam at a pressure of 50 lbs. on the inch, which is first to be gradually admitted into the apparatus, by partially opening the stop-cock *a*, when it passes into the vessel A, where it is allowed to act upon the goods therein deposited, for half an hour; after which the cock *a* may be completely opened, and the full force of the steam allowed to operate, first opening the cocks *b, c, d, e,* when the steam will pass up the pipe D into the vessel B containing the alkaline solution. The pressure of the steam upon the surface of the liquid in this vessel will now cause it to descend through the pipe E into the vessel A, and herein the steam continuing to press, will force the alkaline liquid through the goods, saturating every part, and carrying the dirt and other impurities to the bottom, the liquid passing off through the pipe F into the receiver G underneath. The pressure of steam is next employed to refill vessel B with the discharged alkaline liquor; for this purpose the cocks *b, c, d, e,* are to be closed, and the cocks *f* and *g*, to be opened; the steam will now pass down the pipe H, and operate with its full force upon G, thereby forcing the liquid up the pipe I I again into B, from whence it is again forced through the goods in the vessel A, repeating the operation as often as may be necessary, in order perfectly to cleanse them. The dirt, and other impurities, being removed, the next process is that of rinsing, which is effected by closing the cocks *b, c, d, e, f, g,* and opening those at *h, i, k,* when the steam from C passes up the pipe K into the vessel L, which is filled with clean hot water; the full pressure of the steam being now transferred to the surface of the hot water, forces it through the pipe M and through the goods in the conical vessel A, carrying away all the alkaline and other impurities through the pipe N into the vessel O. The hot liquor in O is now to be returned into L, by closing the cocks *i, k, h,* and opening those at *l, m,* when the steam passes down the pipe P, and forces the liquor contained in O, up the pipe Q Q, again into L, for the renewal of the operation; this part of the process being also repeated as many times as may be deemed desirable, which will depend upon the condition of the goods. The next stage of the process is drying, which is effected by closing all the cocks, except those at *d, e,* and allowing steam, at a reduced pressure, to pass direct from C into the vessel A again, by which all the water is driven out from the goods, leaving them nearly all in a dry state, the steam passing off through the pipe F, and escaping at R. In this part of the process it is necessary to observe that steam should not be employed at a greater pressure than 20 lbs. on the inch, and that its action should not be prolonged beyond the time necessary to drive off the water. For the bleaching of piece goods, in lieu of the circular-sided vessel A, the patentee recommends one with straight sides, diminishing downwards; in this vessel the goods having been carefully folded are to be closely packed, and, in addition to the steaming and washing, by means of alkaline solutions, currents of cold air, produced by a blowing machine, are to be admitted through the pipe S, which, it is said, greatly assists in whitening the fabric.

BLINDS. Screens composed of various materials, and fixed in window frames, either to exclude a too strong light, or to screen the interior of an apartment from the observation of persons on the outside, without obstructing the view of those within. The contrivances for these purposes are numerous, and so well known as to require no particular description; we shall, therefore, only notice a blind for circular headed windows, as these windows are common in modern churches, chapels, and public building, and the heads have hitherto been either left entirely without blinds, or the blinds have been awkwardly contrived, and unsightly in their appearance. *Fig.* 1 is an elevation of the arch of a window; *a a* a metal tube bent so as to fit the head of the window, and serving as a circular curtain rod; this rod is open all along the upper edge, as shown in the section *Fig.* 2; the ends fit into holes at *b* and *c*, made through the window bar at *d;* at *b,* a pulley is fixed, corresponding with the holes and bore of the bent tube *a;* an endless band *e e e Figs.* 1 and 2 enters the tube *a* by the end *c*, goes out at the other end, passes under the pulley *b*, then crosses

the window below the bar *d*, passes over the pulley *c*, and then over a spring catch, or rack pulley, not shown in the drawing. In order to make the blind, a piece of cloth is taken a little wider than the height of the arch, and rather longer than its circumference, and is folded like a fan; a nail is then passed at the

Fig. 1.



bottom through all the folds into the middle of the window bar at *d*, forming a centre to the semicircular tube *a a*; holes are made at the other end in the folds, which allow the blind to slide along the tube; the bottom fold is tacked to the window bar near the end *b*; two pieces of tape connect the upper fold with the endless band by passing through the split tube as shown. The blind is drawn over the window, or withdrawn from it, according as one side or other of the endless band is pulled, as in the common roller blind. The inventor of this excellent contrivance, Mr H. Goode, of Ryde, Isle of Wight, was presented by the Society of Arts with the Silver Vulcan Medal.

BLOCK MACHINERY. The machinery at the Royal Dock-yard, at Portsmouth, invented by Mr. Brunel, for manufacturing blocks, is deservedly celebrated. The following is a concise account of it. The machines are separated into four classes. 1. The sawing machine, for converting the large timber into proper dimensions for the small machines to operate upon. 2. The machinery to form the shell. 3. The sheave-forming machines. And 4. The pin-forming machines. The machinery is capable of completing three sets of blocks of different sizes at the same time, and is worked by two steam-engines of 30-horse power each. The order of the process is this: the elm trees are first cut into short lengths proper to form the various sizes of the blocks, by two large sawing machines, one a reciprocating, and the other a circular saw. These lengths of trees are next cut into squares, and ripped or split up into proper sizes by four sawing benches, with circular saws, and one very large reciprocating saw, which is employed in cutting up the pieces for very large blocks. The scantlings of the blocks being thus prepared, the next process is that of

Making the Shells. The centre hole for the pin of the sheave is first bored by a centre bit in the boring machine, whilst a number of others, corresponding to the number of sheaves which the block is to contain, is bored at right angles to the former, to admit the first stroke of the chisel, and, at the same time, form

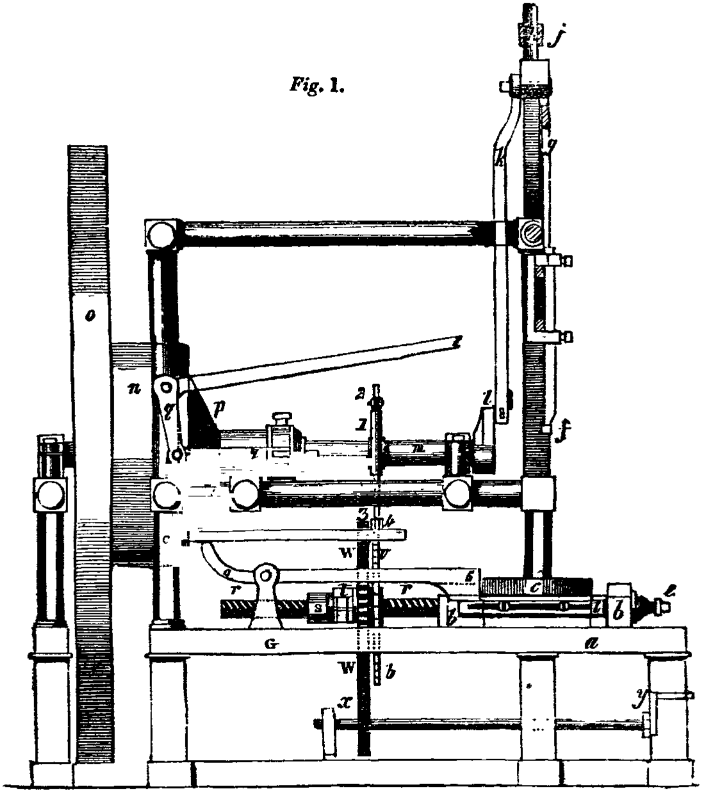
the head of the mortises. The blocks are then removed to the mortising machine; here they are firmly fixed to a movable carriage, beneath cutting chisels, set in a frame moving up and down with extreme rapidity, making, according to Dr. Gregory, 400 strokes per minute. Each time that the chisel frame ascends, the moving carriage advances a small space, bringing a fresh portion of wood under the chisel, until the mortise is cut to the proper length, when the machine is stopped with the chisel frame at its highest elevation. The chips cut are thrust out of the mortise by small pieces of steel projecting from the back of the chisels, which are also armed with two cutters, called scribes, placed at right angles to the chisels, which mark out the breadth of the chip to be cut at each stroke, and at the same time leave the sides of the mortise so true as to require no further trimming. The corners of the block are next taken off at a circular saw table, and it is then removed to the shaping machine; here the blocks are fixed in grooves in the peripheries of two equal wheels fixed upon the same axis, the distance between them admitting of regulation to suit various sizes of blocks, each wheel having ten grooves, so that ten blocks are shaping at once. These wheels are made to revolve with great velocity against a cutter set in a slide rest, which, moving in a curved direction to the line of the axis, cuts those outward faces of the block to their required figure. As soon as the tool has traversed the whole length of the block, the machine is thrown out of gear, and the blocks are (without removing them) each turned one-fourth part round, and another fourth-part of their surface is exposed to the cutter. When the remaining portions of the surface are shaped, the ten blocks are removed, and the last operation is performed by the scoring machine, which, by means of a cutter, scoops out a groove round the longest diameter of the block deepest at the ends, and vanishing at the central hole for the pin. There only remains to remove any little roughnesses, and give the surface a kind of polish, which is done by hand, and the shell is then complete.

Of the Sheaves. These are mostly made of lignum vitæ, which is cut into slabs of a proper thickness by circular saws, and then removed to a crown saw, which bores the centre hole, and at the same time reduces the circumference to a circular figure. The sheave is then placed in the coaking machine, which forms a recess on each side of the block to receive the bush or coak, which is a triangular form, with the ends rounded off. The machinery for effecting this is extremely ingenious, and acts with such accuracy, and the coaks are cast so true, that a single tap with a hammer is sufficient to fix the coak in its place. Three holes are then drilled through the two coaks and the intervening wood, and pins being inserted in the holes, they are placed under the riveting hammer, which strikes the pins with a velocity proportioned to the pressure which the workman exerts upon the treadle. The centres of the coaks are next broached by a steel drill, and the sheave being removed to a lathe, which cuts the groove on the periphery whilst it faces the sides, the sheave is completed. There remains now only the iron pin, which, passing through the two sides of the shell, serves as the axis on which the sheave turns. These pins are also made, turned, and polished, by a machine for the purpose; so that, with the exception of strapping by rope or iron, the block is now complete. The whole cost of the machinery, steam-engine, buildings, interest of money, &c. was 53,000*l.*, and which, by the saving effected by the machine, was completely cleared in four years: Mr. Brunel received on the whole about 20,000*l.* It is calculated that the machine made 140,000 blocks of various descriptions per annum, from the year 1808 to the conclusion of the war, which was found to be not only sufficient for the service of the navy, but also of the ordnance department.

Although the foregoing account of the operations of the several machines will convey to the intelligent reader a sufficiently clear idea of the whole process by which the blocks are made, we doubt not that a representation of some of the principal machines will be acceptable to our readers. To give engravings of the whole of them would cause us to extend this article to too great a length; as, independently of the various saws by which the trees are cut up into blocks and slabs of the proper dimensions, (which saws may be considered as applicable to other purposes), there are a great variety of machines employed in the

subsequent operations. These may be said to constitute the block-making machinery, properly so called; and from these we have selected two of the principal, to form the subject of the accompanying engravings. *Fig.* 1 is a side elevation of the

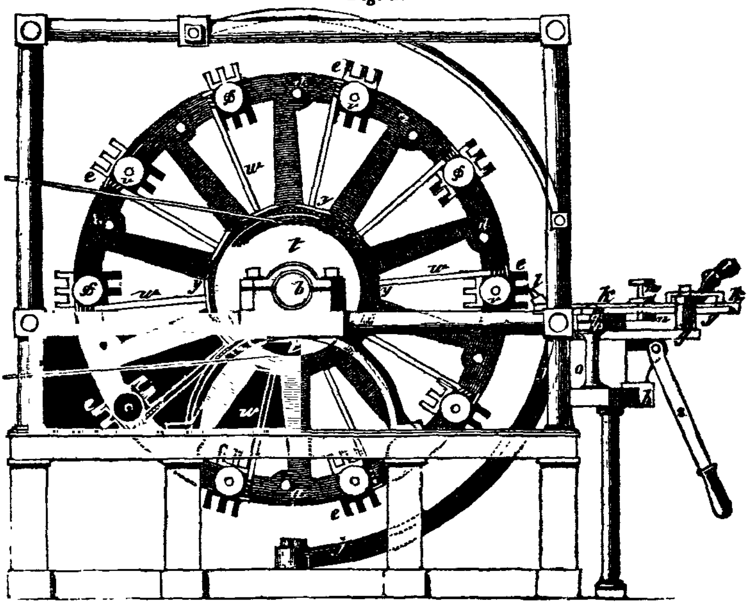
Fig. 1.



mortising machine, in which the mortises for the sheaves are cut. *a a* the bed of the machine; *b* a sliding carriage; *c* the block to be mortised, securely held in the sliding carriage by the screw *e; f* one of the cutters, the number of which depend on the number of sheaves the block is to contain; *g* the cutter frame, moving vertically in guides fastened to the two front pillars of the machine, one of which pillars is removed in the figure, in order to show the cutter frame; *h* a guide rod attached to the upper part of the cutter frame, and moving in a collar *j; k* connecting rod, attached at the upper end to the cutter frame, and at the crank *l* fixed upon the shaft *m*, which is driven by a strap from the steam-engine passing round the drum *n*, which is bolted to the fly-wheel *o*. The fly-wheel is loose upon the shaft, which is attached to, or detached from, the fly-wheel, by a friction-clutch *p*, which enters the conical interior of the drum *n*, and which is moved by the levers *q q; r* is a double-threaded screw, by which the sliding carriage is advanced; it works in a nut *s*, which turns in a bearing *t;* to this nut are attached the rachet-wheel *v* and the cog-wheel *w; x* a pinion acting upon *w*, and turned by the handle *y*, and only used to bring the blocks under the cutters for the first cut, after which the carriage is advanced by the machine in the following manner:—Upon the shaft *m* is an eccentric 1, which acts upon a roller 2 in a vertical lever 3, to the lower end of which is jointed a horizontal bar 4, which has a tooth acting upon the teeth of the ratchet-wheel, so that at each revolution of the axis the eccentric

thrusting out the upper end of the lever 3, moves in an opposite direction the ratchet-wheel *v*, which, by means of the nut *s*, turns the screw, and advances the sliding carriage, so as to bring a fresh portion of the block under the cutters. When the whole length of the mortise is cut, the advance of the carriage further is prevented as follows:—The extremity of the bar 4 is prolonged beyond the ratchet-wheel, and rests upon the lever 5, which turns upon a pin in one of the upright columns of the frame. The lever 5 is supported by the curved end of the lever 6, the other end of which rests upon an adjustable slide 7, which is screwed to the sliding carriage, and which is so fixed, that when the mortise is completed, the long arm of the lever 6 is no longer supported by the slide; the long arm of the lever consequently descends, and, by its descent, raises the lever 5, which lifts the bar 4 clear of the teeth of the ratchet-wheel. *Fig.* 2 is a side elevation of the shaping machine; *a* is a large circular rim, or

Fig. 2.



chuck, firmly keyed upon the shaft; *b* a similar chuck; *c* (which cannot be shown in the drawing) is placed upon the shaft behind *a*. This chuck is not made fast, but may be set upon the shaft at any required distance from *a* to suit the different sizes of the blocks; *d d* are stay bolts passing through the chucks *a* and *c*, and having nuts at the back of *c* to retain it at the requisite distance from *a*; *e e* are the blocks which are to be shaped; they are retained between the two chucks *a* and *c*, as follows: *f f* are a number of short maundrils, set in the chuck *a*, and each carrying on the farther end a small cross, the extremities of which have two sharp steel rings; in the chuck *c* is a screw, opposite to, and concentric with, the maundrils *f f*; the inner end of these screws having a sharp steel ring loosely fitted upon them. Each block, in the operation of boring the holes previous to passing to the mortising machine, has had the line of its axis determined, by the marks of two steel rings impressed on one end, and of a single ring upon the other. The marks of the two rings are applied to the steel ring on the cross, and the ring on the screw is advanced by the screw to the single mark on the other end of the block; *g* is a slide rest, supported upon the bed *h*, and attached to the radial bar *j*, which turns upon a centre directly beneath the line of the axis of the shaft *b*; *k* is the bar carrying the cutter *l*, and sliding

in a mortise; *m* a steel spindle, passing through a socket in *k*, and having a small horizontal roller *n* fitted upon its lower end; *o* one of two pillars supporting two curved bars *p q*, called shapes; the curve on one bar determining the shape of the faces of the blocks, and that of the other bar the shapes of the sides of the blocks. *r* is a lever by which the cutter bar is moved along its mortise, so as to cause the roller *n* to press against one of the shapes *p* or *q*; *s* is a bar attached to the slide rest, by which the rest is made to traverse the bed *h*, describing a portion of a circle of which the pivot of the radial bar is the centre. The operation of the machine is as follows: the chucks being filled with a number of blocks corresponding to the number of maundrils, the chucks are set in motion by a strap from the engine passing round the drum *t* keyed upon the shaft *b*. The cutter *l* being previously adjusted to the proper distance, the attendant holding the bar *s* in his right hand, causes the slide rest slowly to traverse the bed *h*, whilst, by the lever *r*, held in his left hand, he keeps the roller *n* in contact with the shape *p* or *q*, and consequently causes the cutter *l* to describe a curve similar to that of the shape; and that face of the blocks which is exposed to the cutter revolving with extreme rapidity against the cutter, is cut to a corresponding shape. When the first side is completed, the blocks and the chucks are stopped, and the blocks are turned one-fourth round, so as to present the next side to the cutter. This is effected by the following means: on the outer end of each maundril is fixed a worm wheel *v*, upon which an endless screw upon the outer end of the spindle *w* acts; upon the other end of each spindle is fixed a bevilled pinion *y*, gearing with a bevilled wheel *x*, fitted loose upon the axis. When it is required to turn the block, the wheel *x* is locked to the frame by a catch pull (not shown) and the attendant turns round the chucks *a* and *c* four times, and the bevilled pinions revolving round the wheel *x* cause the spindles on which the endless screw is cut to turn the worm wheels one-quarter round. The roller *n* is then by a simple movement pushed down, so as to act against the lower shape; the chucks are again set in motion, and the slide rest being made to traverse back over the bed, the second face is shaped, and the operation is repeated for the other two sides.

BLOCKS, in the Navy, and Marine Architecture, a species of pulley very extensively used for moving heavy weights, by means of ropes or chains passing over the pulleys; also occasionally in architectural and other works. A block consists of one or more pulleys, called sheaves, which are generally formed of lignum vitæ, or some hard wood inserted between cheek-pieces forming what is called the shell of the block, and turning upon a pin passing through the shell and the centres of the sheaves. Blocks are of various forms, each having a particular name; the following cut represents a common single block; *a* is the shell, *b* the sheave, *c* the pin. Blocks are suspended by straps, either of rope or iron; the latter are called iron-strapped blocks, and have frequently a swivel-hook. A combination of two blocks, one of which is attached to the load to be raised, is called a tackle, and the power is to be estimated by the space through which the fall (which is that part of the rope to which the power is applied) passes, compared with the space through which the load is raised, deducting for friction, which is great, owing to the rigidity of the ropes, and the small diameter of the sheaves; these, for nautical purposes, are necessarily limited by considerations as to weight and space. The friction is also considerably increased, in certain circumstances, under which blocks are applied. When there is more than one sheave in the same block, the fall comes last over the outside sheave; and that sheave, if the exertion of power be in a line nearly parallel to the direction in which the load is drawn, always endeavours to get into a line with the point of suspension; for the great friction to be overcome preventing the equal transmission of the power throughout the combination, and the outside sheave having to sustain not only the pressure of its own share of the load, but also the additional strain sufficient to overcome the friction of the other sheaves, and the vis inertiæ of the entire load; it must, therefore be considerably depressed, and in consequence of this oblique direction of the block, the lateral friction of the sheaves becomes so great, as in some cases nearly to equal the power. *Figs.* 1 and 2 represent blocks so constructed as to allow

Fig. 1.

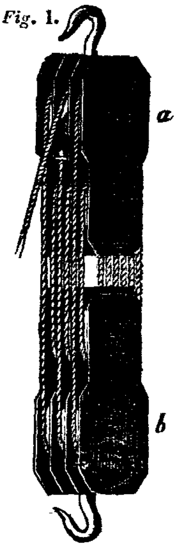
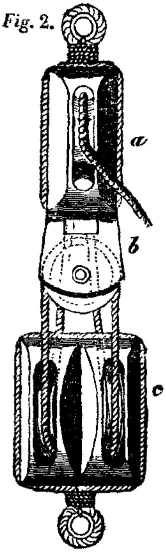
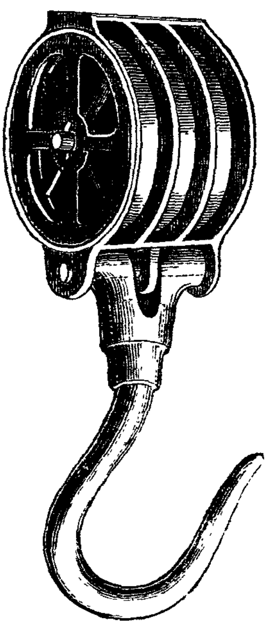


Fig. 2.



the fall to pass over the middle sheave, by which means it will be immediately beneath the point of suspension. *Fig.* 1 is the invention of the celebrated Smeaton, who employed blocks of this description in erecting the Eddystone Light-house. The upper block *a* contains 6 sheaves ranged in two tiers, and the lower block *b* contains also 6 sheaves, also ranged in two tiers; the lower tier of sheaves in *a*, and the upper tier of sheaves in *b*, being more than two diameters of the rope smaller than the other sheaves, the mode of reeving the rope is as follows. Beginning in the middle, the rope is reeved over the large sheaves as far as it will go; thence going to the first of the smaller sheaves, they are reeved throughout; thence again to tne outer one of the remaining large sheaves, and ending upon the middle sheave of the upper block. The principal objection to this method is, that it requires a combination of at least twelve sheaves, and is not therefore applicable to general purposes. The construction shewn in *Fig.* 2, which is the invention of Mr. Jones, of High Holborn, can be applied to any number of sheaves from 4 upwards. The cut represents a pair of blocks of 2 sheaves each. To the upper block *a* is attached another block *b*, the sheave of which stands at right angles to the former, and is called the cross-sheave; the lower block *c* contains two sheaves abreast, (shewn diverging,) in order that the cross sheave may not be of a very small diameter. The method of reeving is to begin upon the middle upper sheave, and when arrived at the outer sheave, to pass to the cross sheave, which carries the rope over to the outer sheave, on the opposite side, and then proceed again in the order of the sheaves.



The annexed figure represents an improved cat-block, invented by Mr. Bothway, and rewarded by the Society of Arts. The advantages which this block possesses over those in common use, are thus stated by Mr. Bothway. "In all large class ships in the royal navy, the unwieldy nature of the usual cat-block requires that two men should be sent out on the anchor, a most perilous service in rough weather; whereas mine only requires one man at any time, because he has not to sustain the whole weight of the block, as in the former case, but only that of the hook. And in vessels smaller than line of battle ships, in blowing weather, when the ship pitches heavily, the anchor may be hooked without a man going on it, by his standing on the head, and guiding the hook of the block to the anchor, by a staff and hook, similar to a boat-hook. This facility is gained by the mobility of the swivel in its socket, so that the man has not the weight of the block to turn, in order to insert the

hook in the ring of the anchor. Should the anchor, when hooked in the dark, or otherwise, cause a turn in the fall, the hook being on a swivel joint, the turn will come out before the strain comes on the block; and when the anchor is foul it can also be hooked with great facility. In my thirty-two years' service I have seen the wooden cat-blocks swell so much in cold climates, that the sheaves have become immovable; mine, being of metal, are liable to no such inconvenience." Another great advantage may be derivable from Bothway's cat-block being applicable to other uses; whereas the old ones are not. For instance, by merely having a spare socket or two fitted with hooks of various sizes, it may take a strap for gear-blocks, or it may be converted into a lashing-block without the hook and socket, but with the socket bolt. In the figure, which represents a perspective view of the block, it will be seen that the hook, instead of being formed in one with the strap, turns with a swivel head, in a socket which hangs from a pin passing through the lower end of the shell. Although entirely formed of metal, they are lighter than wooden ones with their iron bindings, and capable of the same service.

There is another species of blocks, which are termed "*Dead eyes*," and are used for tightening or setting up, as it is called, the standing rigging of ships. It consists merely of a circular block of wood, with a groove on its circumference,

Fig. 1.

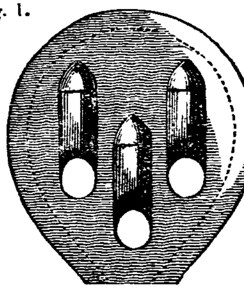


Fig. 2.

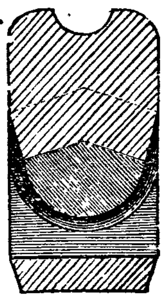
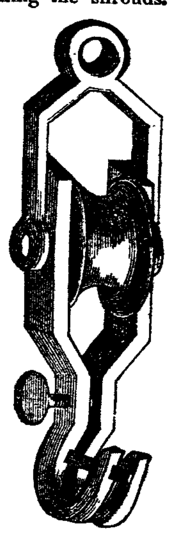


Fig. 3.

round which the lower end of the shroud, or an iron strap, is fastened; three holes passing through the face, (ranged in a triangle,) to receive the laniard or smaller rope, which forms a species of tackle for tightening the shrouds. There are no sheaves in the dead eye, but the edges of the holes are rounded off to prevent cutting the laniard, but this very imperfectly answers the purpose; as from the roughness of the grain of the wood, which is usually elm, and from the stiffness of the rope, the laniard renders with difficulty, and from the great strain to which it is subjected, it is frequently broken. A very simple and effectual improvement has been made in this respect by Mr. Carey, Surveyor of Shipping, at Bristol, by inserting a half sheave of lignum vitæ into each of the holes, which causes the laniard to render with greater facility, and the shroud to be set up in half the usual time. *Fig.* 1 shews the dead eye; *Fig.* 2 a section of the same; and *Fig.* 3 one of the half-sheaves. It will be seen from the manner of inserting the half sheaves, as shown in *Fig.* 2, that they cannot fall out, for the more pressure there is on them, the faster they will be.



The annexed figure represents a block of a peculiar description, intended for forming a kind of rope-road to a stranded ship. When a vessel thus circumstanced has had a rope thrown over by Capt. Manby's apparatus, or any other means, considerable difficulty has been found in reeving an ordinary pulley for the conveyance of the crew to the shore. In the figure, it will be seen that the pulley divides at the hook, or shackle, into two equal parts, so that it may be

instantaneously passed on to a stretched rope, and, by means of a cord from the ship, persons may pass securely and quickly backwards and forwards. The little bar which traverses the opening is fixed at one end by a joint, and fits into a mortise, as shown; the use of it being to confine the rope in its place, when any vehicle, or other apparatus, is slung or suspended to it.

BLOOD. The principal use of blood in the arts is for making Prussian blue, or sometimes for clarifying certain liquors. It is also recommended in agriculture, as an excellent manure for fruit trees. A mixture of blood with lime makes an exceedingly strong cement; and hence its use in the preparation of some chemical lutes, the making floors, &c.

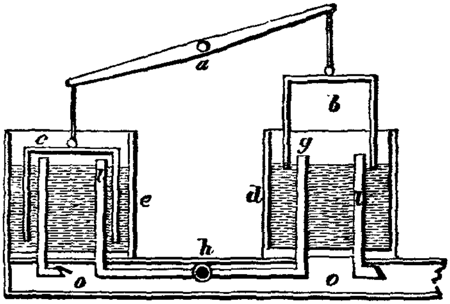
BLOOM. A mass of iron after having undergone the first hammering, called bloomary. It requires many subsequent hammerings or rollings to render it fit for smiths' use. See Iron.

BLOTTING PAPER. A species of paper made without size, serving to imbibe the wet ink in books of account, &c. See Paper Making.

BLOWING MACHINES. Machines employed for producing a rapid combustion of fuel, by furnishing a more copious supply of air than can be obtained by the mere draft of the ordinary chimneys. Although the common bellows is undoubtedly a blowing machine, yet the term is generally restricted in its application to those machines which are employed at large furnaces, as in foundries, forges, &c. Blowing machines are constructed of various forms, the great object in all being, that the blast should be as continuous and uniform as possible. The method of producing such blast by a centrifugal force has long been known, but the first blowing machine on this principle, of which we have a distinct account, is that invented by Mr. Teral, in 1729. It consists of a number of vanes or fanners, radiating from a horizontal shaft, and enclosed within a cylindrical box, having two apertures at opposite sides of the cylinder, to one of which is fitted a conical pipe leading to the furnace, whilst the air enters by the other aperture, and the shaft being turned with great rapidity, a copious and uniform current of air may be impelled through the conical pipe to the furnace. From the great simplicity and cheapness of these machines they have recently been coming into more general notice.

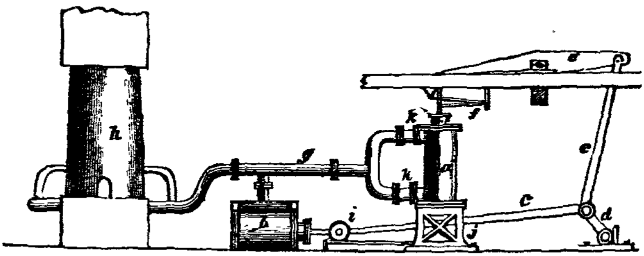
Another kind of blowing machine, and which is very extensively used for smiths' forges, is the double bellows. This machine in form resembles an ordinary single bellows, but is divided into two parts by a middle board, similar to the bottom board, and like it furnished with a valve opening upwards. The upper and under boards are each loaded with weights, which compress the upper and distend the lower compartments, and the middle board is supported in a horizontal position upon a frame. The pipe or nozzle of the bellows communicates with the upper compartment of the bellows only whilst the air is admitted by the valve in the lower compartment. The action of the machine is as follows: The lower board being raised by the brake or handle, the air contained in the lower compartment is driven through the valve in the middle board into the upper compartment, and not escaping from it through the nozzle, as fast as it is forced into it, it elevates the upper board, and thus distends the upper compartment. Upon the descent of the lower board, the valve in the middle board closes, and the upper board descending by the pressure of the weights upon it, the air beneath it is urged through the nozzle in a continuous current. During the descent of the lower board, the air enters by the valve in the board, and fills the lower chamber of the bellows; and upon the rise of the board it is forced into the upper chamber as before, and thus a continuous blast is maintained. But although continuous, it is not quite equal, or of a uniform force; for during the up-stroke the air is compressed by a force exceeding that of the weights on the upper board, since it causes the upper board to ascend; but upon the descent of the lower board, the air is expelled by the pressure of the weights alone, which, being at all times the same, the current is then nearly uniform.

Another species of blowing machine is the water bellows, invented by Hornblower, several of which machines have been erected in various parts of the country. The nature of these machines will be readily understood by the



help of the following diagram The side figure is a vertical section of the machine. *a* is the fulcrum of the lever or beam, with two inverted vessels *b* and *c* suspended from its extremities; these vessels are open underneath, but air-tight above. *d* and *e* are two larger vessels, filled with water to the same level in which the vessels *b* and *c* rise and fall alternately. *g h i* is a tube or pipe, which passes through the vessels *d* and *e*, and reaches above the surface of the water; at the extremities are two valves, (omitted by mistake) which respectively open outwards into the inverted vessels, with a pipe at *h* open to the atmosphere. *k* and *l* are pipes passing through the bottom of *d* and *e*, and extending a little above the surface of the water; they are open at top, and have valves at bottom opening into the trunk *o*, to which the pipe is fitted which conducts the blast to the furnace. An alternating motion being imparted to the beam by a steam engine or other first mover, the air passes up the tubes *g h i* and fills each inverted vessel as they are successively drawn up out of the water; the descent of the inverted vessel closes the valves at *g* and *i*, and opens those at the bottom of the tubes *k* and *l*, through which the air is driven forward by the trunk *o*, and thus, by the reciprocation of the beam, a continual blast is maintained through the trunk *o* and the tuyere of the furnace.

But the most perfect blowing machines are those in which the blast is produced by the motion of pistons in a cylinder. The annexed engraving represents a blowing machine of this description, erected by Mr. Paterson, of Lanark. It consists of two double acting force pumps, placed at right angles to each other, to equalize the draft; they are driven by a water-wheel of 5-horse power. *a* is



the vertical cylinder; *b* the horizontal cylinder; *c c* two connecting rods united to the crank *d*; *e* the working beam; *f* the parallel motion; *g* the pipe for conveying the blast to the cupola or furnace *h*; *i* a small wheel, running in a groove in a cast iron plate; *j* frame supporting the vertical cylinder, between which the lowermost connecting rod *c* passes. At *k k* are placed valves, to admit the air into the vertical cylinder; similar valves are placed at the ends of the horizontal cylinder into it. The operation is simply this: by the revolution of the crank the air is drawn in at each end alternately of both cylinders, and at the same time it is forced out at the opposite extremity along the pipe *g* into the furnace; and the cylinders being placed at right angles, one piston will be moving with its greatest velocity whilst the other is moving with its least velocity, by which means the blast is rendered nearly uniform, and an air chamber or reservoir rendered unnecessary. The first cylinders of magnitude used as blowing machines, were erected by Mr. Smeaton, in 1760, at the Carron Iron Works, the cylinders being four in number, 4 feet 6 inches in diameter, and the piston making a stroke of 4 feet 6 inches in length; but the blowing machine lately

erected at the Smithery, in the Royal Dockyard at Woolwich, is perhaps the most powerful and the most complete in the kingdom.

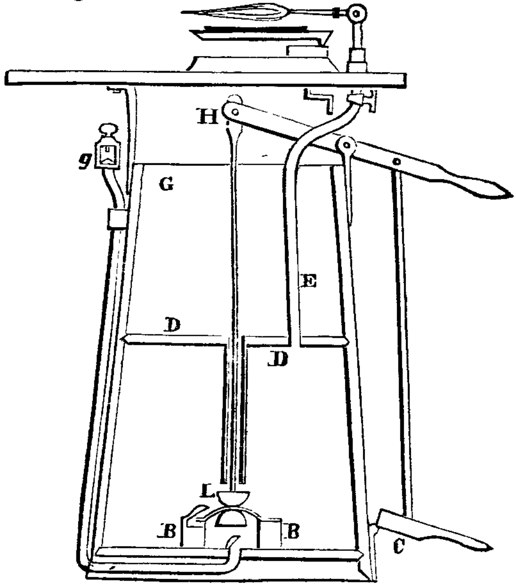
In this machine there are three blowing cylinders, of 4 feet 8 inches diameter, with a stroke of 4 feet 8 inches, and each cylinder making 20 strokes per minute, expelling near 5000 feet of air per minute. Over the wind chest is fixed a regulating cylinder, which has no bottom, being open to the wind chest; and its piston, which weighs 700 lbs. serves only to regulate the pressure, which amounts to about ¼ lb. per square inch. When the pressure exceeds this, the piston rises, and opens an escape valve at the back of the cylinder.

BLOW PIPE. An instrument for exciting intense combustion upon a small scale; it is extensively used in many branches of the arts, and also in philosophical experiments upon metallic substances. In its simplest form it is merely a conical brass tube, curved at the small end, in which is a very minute aperture; and a stream of air being urged through it by the mouth against the flame of a lamp or candle, a heat equal to that of the most violent furnaces may be produced. The body intended to be operated upon should not exceed the size of a peppercorn, and should be supported upon a piece of well-burned close-grained charcoal, unless it be of such nature as to sink into the pores of the charcoal, or to have its properties affected by its inflammable quality. Such bodies may be placed in a small spoon made of pure gold, silver, or platinum. Many advantages may be derived from the use of this simple and valuable instrument. It is portable; the most expensive materials, and the minutest specimens of bodies, may be used in the experiments; and the whole process is under the eye of the observer. In the blow pipes used by enamellers, glass-blowers, and others, the current of air is maintained by a small pair of double bellows.

Early in the present century, Dr. Hare, of Philadelphia, made a most important improvement in the blow pipe, by substituting for the flame of a lamp that arising from a mingled current of oxygen and hydrogen, by which means he succeeded in producing a more intense heat than had ever been obtained before, except by the concentration of the sun's rays in very large and powerful lenses. As these gases, however, can only be procured by chemical means, a more perfect method of supplying the currents of gas than by means of the common bellows became desirable, on account of the great leakage of the latter, and the Doctor, turning his mind to the subject, devised a machine equally applicable for supplying either oxygen gas or common air. This machine, which he denominated the Hydrostatic Blow Pipe, is represented in the annexed engraving, of which the following is an explanation.

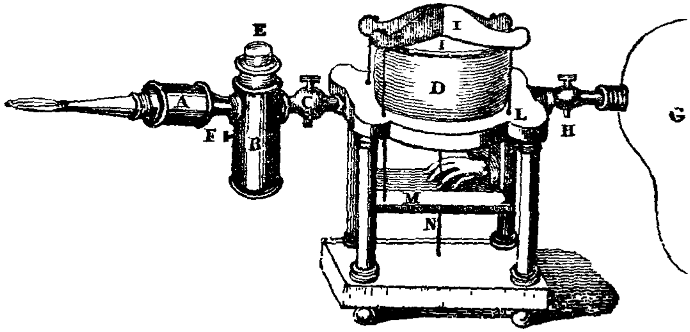
The Hydrostatic Blow Pipe consists of a cask, divided by a horizontal diaphragm into two parts D D. From the upper apartment, a pipe of about 3 inches diameter (its axis coincident with that of the cask) descends, until within about 6 inches of the bottom. On this is fastened by screws, a hollow cylinder of wood B B, externally 12 inches in diameter, and internally 8 inches. Around the rim of this cylinder a piece of leather is nailed, so as to be air-tight. On one side a small groove is made in the upper surface of the block, so that a lateral passage may be left when nailed on each side of the groove. This lateral passage communicates with a hole bored vertically into the wood by a centre bit; and a small strip of leather being extended so as to cover this hole, is made, with the addition of some disks of metal, to constitute a valve opening upwards. In the bottom of the cask there is another valve opening upwards. A piston rod, passing perpendicularly through the pipe from the handle *h*, is fastened near its lower extremity to a hemispherical mass of lead L. The portion of the rod beyond this proceeds through the centre of the leather which covers the cavity of the wooden cylinder, also through another mass of lead like the first, which, being forced up by a screw and nut, subjects the leather between it and the upper leaden hemisphere to a pressure sufficient to render the juncture air-tight. From the partition, an eduction pipe E is carried under the table, where it is fastened by means of a screw to a cock which carries a blow-pipe, so attached by a small swivel joint, as to be adjusted in any required direction. A suction pipe passes from the opening covered by the lower valve, under the bottom of the cask, and rises vertically close to it on the

outside, terminating in a union joint for the attachment of any flexible tube which may be necessary. The apparatus being thus arranged, and the cask supplied with water until the partition is covered to about the depth of 2 inches, if the piston be lifted, the leather will be bulged up, and will remove in some degree the atmospheric pressure from the cavity beneath it, consequently the air must enter through the lower cavity to restore the equilibrium. When the



piston is depressed, the leather being bulged in an opposite direction, the cavity beneath it is diminished, and the air being thus compressed, forces its way through the lateral valve into the lower compartment of the cask, which compartment being previously full of water, a portion of the fluid is pressed up through the pipe into the upper apartment. The same result ensues each time that the stroke is repeated, so that the lower compartment soon becomes filled with air, which is retained by the cock until its discharge by the blow pipe is necessary. Dr. Hare, in his oxy-hydrogen blow pipe did not mix the gases in his gas reservoir, but supported the flame of the hydrogen by a current of oxygen issuing from different jets. Subsequently, it was found that the heat produced was materially affected by the *proportions* in which the gases were mixed, and that the greatest intensity of heat was obtained by two volumes of hydrogen united with one of oxygen; and various attempts were made to mix and *burn* the gases in their due proportion, but with little success, until the important improvement effected in the instrument by Dr. Clarke, Professor at Cambridge. This improvement consisted in first mixing the gases in a bladder, in the exact proportions to form water, and afterwards condensing them in a strong iron chest, by means of a condensing syringe. To an opening at the end of this chest he attached a great number of layers of fine wire gauze, through which the mixed gases were driven by their elastic force into a small tube, at the end of which they were inflamed. By this arrangement he obtained a much greater heat than had been effected by Dr. Hare's invention, and was enabled to make a great number of experiments highly interesting to science. Unfortunately, however, for the general adoption of his plan, it was soon found that his instrument was unsafe to use; *that the wire gauze would not prevent the explosion of the gases;* that in several cases, when used by the most experienced and cautious operators, the instruments were burst. The explosions were tremendous, and resembled the bursting of a bomb, the fragments of the iron

chest being scattered with great force in all directions. After trying various plans to render the invention safe, the Doctor, as a protection, had the iron chest placed behind a brick wall at the back of the operator, the gases being conveyed through a tube passing through the wall. In this state the instrument remained, until Mr. Goldsworthy Gurney applied himself to its improvement, and after numerous experiments, which are highly interesting, and are fully detailed in his published lectures, he succeeded in producing an instrument unattended with the slightest danger in its use, and admirably adapted both for scientific investigation, and for various operations in the arts. The annexed engraving is a



representation of the instrument. A is the safety chamber; B a water trough, through which the gas is made to pass from the gasometer D by the cock C, through a tube which reaches to the bottom of the water trough; E is a cock fitted into the neck of the same, from which it is thrown out should an explosion take place on the surface of the water. F is a gauge, to indicate the necessary height of the column of water in the trough. G is a transferring bladder, which is made to screw and unscrew to and from the stop-cock H, for the purpose of supplying the gasometer with gases, which may be charged and recharged at pleasure, by an assistant, during its action, so as to keep up the most intense flame for any length of time. A valve is placed between the gasometer and the transferring bladder, which prevents the return of the gas. I I is a light wooden or stiff pasteboard cap, which combines sufficient strength with great lightness, so that in case an explosion of the gasometer should happen, it is merely thrown a short height into the air, by the force breaking the strings which connect the cap to the press board. To these strings are attached small wires, which pass through the table of the instrument, as at L, into the press-board below, where they are secured; this press-board is kept in a horizontal position by the stand, so that when the requisite pressure is given to it, the cap I I is brought to bear equally on the gasometer D. The gasometer bladder (or silk bag) is tied to a piece of bladder, which screws into a long tube laid into and across the table, which permits it to be unscrewed at pleasure from the body of the instrument, and immersed in water when it requires softening, affording also the means of fixing on another bladder, if any accident should render it necessary. The stop-cock of the charging bladder G is fixed to one end of the tube just described, and the stop-cock of the water trough on the other end. To operate with this instrument, pressure by the hand is applied to the press-board, which draws down the cap I I on the gasometer D, and forces the gas which it contains through the stop-cock C, and through the water tube and safety chamber A, to the jet at the end, where it is burned. When the pressure on the press-board is too slight, or when the hand is taken off, the flame returns into the safety chamber, and is extinguished. When it is required to suspend the operation, the hand need only be taken off the pressing board, the water in the trough acts as a self-acting valve in preventing the escape of gas from the instrument, and saves the necessity of turning the stop-cock. A silk tube is attached to the end of the tube before described, in the water trough, which

prevents the splashing of the water, sometimes occasioned by unskilful management. We omitted to state that the safety chamber A is filled with numerous discs of very fine wire gauze closely packed, and should the flame be driven in, which will sometimes happen, it will not enter the bag or reservoir D, but will explode above the surface of the water in the chamber B, merely driving out the cork. An improvement has, however, been since introduced in the construction of the safety chamber, by Mr. Wilkinson, of Ludgate-hill, by which the retrogade motion of the flame appears to be effectually prevented, and a much larger jet may be employed than heretofore with perfect safety. This improvement consists in filling the chamber A with alternate layers of wire gauze and of asbestos, previously beaten with a mallet, and pulled out to resemble floss silk. Mr. Wilkinson received from the Society of Arts a silver medal, for his communication on the subject, and we understand that Mr. Hemming has recently made some further improvements in the construction of the instrument. We must here advert to the wonderful effects produced by the oxy-hydrogen blow pipe, which almost instantaneously reduces the hardest and most refractory substances. Gun flints are instantly fused by it, and formed into a transparent glass; china melts into a perfect crystal. All kinds of porcelain are readily fused, previously assuming a beautiful crystallized appearance. Rock crystal is quickly melted, giving out a beautiful light. Emerald, sapphire, topaz, and all the other precious stones, melt before it into transparent glassy substances. Barytes, strontian, lime, and alumina, exhibit very striking and beautiful phenomena. Magnesia fuses into hard granular particles, which will scratch glass. The metals, even platina, are *all* quickly fused by it; and all descriptions of stones, slates, and minerals, are melted, sublimed, or volatilized, by its all-subduing power.

BLUBBER, in Physiology and Commerce, the fat which invests the bodies of all large cetaceous fishes, serving to furnish an oil. The blubber lies immediately under the skin, and over the muscular flesh. In the porpoise it is firm and full of fibres, and invests the body about an inch thick. In the whale its thickness is ordinarily 6 inches, but about the under lip it is found two or three feet thick. The quantity yielded by one of these animals ordinarily amounts to forty, or fifty, sometimes to eighty or more hundred weight. Its use in trade and manufactures is to furnish train-oil, which it does by boiling down. Formerly this was performed ashore in the countries where the whales were caught, but lately the fishers do not go ashore; they bring the blubber home stowed in casks, and boil it down there. A machine expressly designed for expressing the oil from blubber is given under the word Oil.

BLUE (Prussian). A very fine blue pigment, extensively used in the arts. It is composed of prussiate of iron, and the earth precipitated from alum or pure alumine. It is commonly obtained by calcining blood or other animal substances, as hoofs, horns, parings of leather, &c. by which a black coaly residuum is obtained. Three parts of this are added, at intervals, to four parts of potash, kept in a state of fusion in a stout iron vessel, the mixture being constantly stirred during the process. At first a reddish flame appears upon the surface of the mass; this afterwards changes to a bluish tinge, denoting the formation of prussiate of potash, when the whole is to be removed as speedily as possible into a large vessel of boiling water, and stirred, to promote the dissolution of the prussiate of potash. After allowing the dregs to settle, the clear liquor is drawn off, and fresh quantities of water boiled upon the residuum, until it ceases to impart much taste to the water; and the whole of the liquor thus obtained being mixed together, a solution of alum and green vitriol is added, when a precipitate of Prussian blue is immediately formed, which is washed repeatedly to free it from the sulphate of potash; after which it is put into bags and pressed, and then exposed to the air to dry, during which process it assumes a deeper colour, and acquires a hard stony consistence.

BLUE (Powder or Stone), used in washing linen, is the same with smalt, either in the lump or powder. When the smalt is taken from the pot, it is thrown into a large vessel of cold water; this makes it more tractable, and more easily powdered. When examined after cooling, it is found to be mixed with a greyish matter resembling ashes, which must be separated by washing and

then the blue substance being powdered and sifted through fine sieves, forms what is called powder blue.

BLUE (SAXON). The best Saxon blue may be prepared as follows:—mix 1 oz. of the best powdered indigo with 4 oz. of sulphuric acid in a glass bottle or matrass, and digest it for one hour in a water bath, shaking the mixture at different times; then add 12 oz. of water to it, stir the whole well, and when cold, filter it.

BOAT. A small vessel for the conveyance of goods or passengers to short distances, and which may be impelled either by oars or sails at pleasure. They are for the most part open or without decks; but the varieties in their form and construction, according to the purposes for which they are intended, are so great as to preclude enumeration. Boats always form part of a ship's equipment; the number depending upon the size of the vessel, and the service for which it is intended. Of these the cutters, gig, and jolly boat, are principally employed for the conveyance of officers and crews on any service; and the long boat or launch, for the conveyance of heavy stores of every description to and from the vessel. The engraving represents an improvement in this latter class of boats, when employed for laying out and weighing heavy anchors, and for landing and embarking cannon. The usual mode of laying out anchors by means of a ship's launch is, to place the anchor over the boat's stern, and to coil the cable on the gunwale; but this lumbers up the boat, overloads it, and exposes it to the danger of being swamped in a high sea. To obviate this, attempts have been made to sling the anchor beneath the boat, as near as possible in the centre of gravity of the boat; none of these, however, succeeded so as to encourage their adoption. Subsequently, Mr. Cow (master boat-builder of the Royal Dock, at Woolwich,) devised the present arrangement, which was so much approved by the Navy Board, that they have directed that every ship of war of a certain class shall be furnished with a launch fitted on Mr. Cow's principle, and the Society of Arts have rewarded him with a gold medal for the invention. The former method (alluded to above) for carrying an anchor under a boat's bottom, was to have only one *fixed* trunk, which was in the middle of the boat, close to the side of the keel; the windlass, therefore, could only be supported at the ends, and was unequal to the heaving up any great weight; the great strain also was entirely on the sides of the boat. By Mr. Cow's plan there are two *movable* trunks at a proper distance from the keel, thereby allowing a strong stanchion to be placed on the kelson, which stanchion supports the middle of the windlass, and consequently makes it of sufficient strength to weigh any weight that the boat is able to sustain. *Fig.* 1 gives a perspective view of a 74-gun ship's

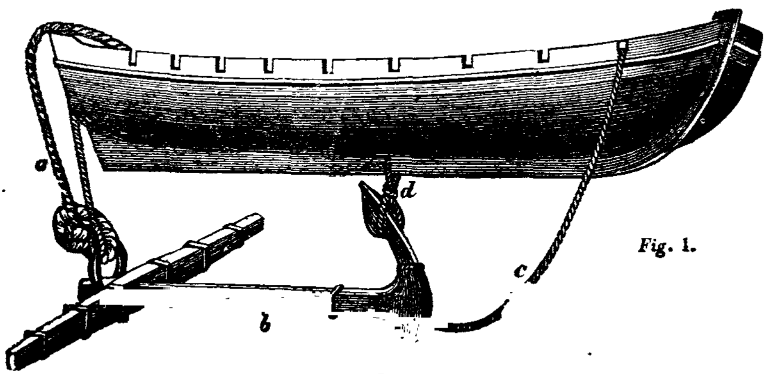
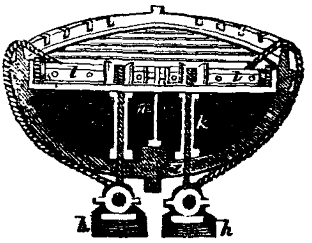


Fig. 1.

launch, with a bower anchor suspended under the bottom, and a bower cable coiled into the boat. *a* is the cable; *b b* the anchor; *c c* the buoy rope; *d* a

rope by which the anchor is hove up when weighing, or suspended when carrying, by the windlass. *Fig.* 2 gives a mid-ship section of the launch, with two 32-pounders suspended from the windlass. *h h* the guns lashed to wooden slides; *i i i* ropes by which the guns are hove up to the boat's bottom; *k k* water-tight removable wood trunks, through which the ropes pass to the windlass; *l l* the windlass in two parts connected by a wrought iron gudgeon and socket; *m* a removable strong wrought iron stanchion, which supports the middle of the windlass. The application of the invention to the purpose of landing and embarking heavy guns is also of great importance, as it enables this operation to be conducted on a beach with perfect safety to the men and boats, at times when the surf is so great as to preclude the possibility of boats approaching near enough to land or to embark in the usual way; for the boat (with two guns suspended one on each side of the keel, as shown in *Fig.* 2) being brought to anchor without the surf, a small line is the only connexion necessary with the shore, by which line the larger hauling ropes are conveyed, which being made fast to the guns, the latter are lowered from the boat, and hauled upon the beach. Should the operation be carried on where there is a rise and fall of the tide, and the guns should not be immediately wanted, it will be only necessary to take the boat in at high water, and drop the guns, which may be taken up as the tide leaves them; in either case the boat is fit for any other service, without risk of damage by being kept afloat. The interior of the boat is kept clear for stowing the carriages and other stores. The embarking of guns is performed in the same way, care being taken to have anchors of sufficient power to moor the boat without the surf, so as to counteract the weight of the guns, and the resistance it meets with in being hauled off from the shore.

Fig. 2.



Boats and small vessels are sometimes built flat-bottomed, to allow of their going into shoal water when required; and in order that they may carry a sufficient quantity of sail, and to prevent their making lee-way, they are fitted with what are termed sliding keels. These were first introduced into this country by Admiral Schank, at whose instance a government vessel, which was destined for a surveying vessel at New Holland, was fitted with them. These sliding keels consisted of three stout planks, descending through water-tight wells to a considerable depth below the ship's bottom, and fitted with apparatus for raising or lowering them at pleasure. The narrow edge of the plank being in the line of the vessel's keel, presented but little resistance to the vessel's sailing, whilst the pressure of the water upon the broad surface of the keels tended to counterbalance the effect of the wind upon the sails, to depress the ship, and materially lessened the rolling, and also prevented the vessel going to leeward, as she must otherwise have done, owing to her extreme light draft of water. Although a favourable report was made of the invention, it was never very generally adopted, but it has since been made the subject of a patent, under a somewhat different form, by Moncrieffe Willoughby, Esq. In his arrangement a sliding keel of iron, made very massive, is firmly attached to strong perpendicular iron bars, which are made to slide up and down in water-tight grooves made through the centre of the hull, thus permitting the keels to be projected to any required depth in the water, and to be drawn up at pleasure by means of a simple rack and pinion worked by a winch upon the deck. The sliding keel is further secured or supported by four chain stays, two on each side, which pass over the gunwales, and are tightened on board. *Fig.* 1 is a side elevation of a vessel fitted with a sliding keel on Mr. Willoughby's construction. *Fig.* 2 a cross section of the vessel, through one of the water-tight trunks of which the suspending bars pass. *Fig.* 3 a cross section, exhibiting the guys or stays attached to the sliding keel. In *Fig.* 4 the ballast keel in front of the suspenders is cut off, for the purpose of preventing the

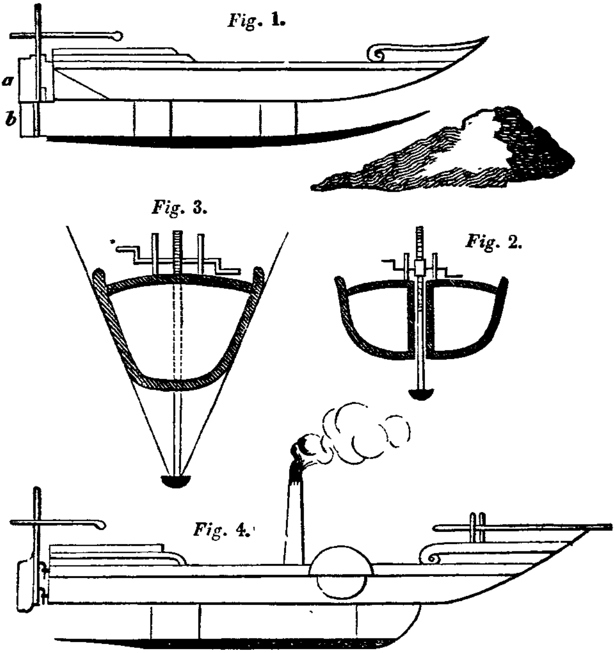
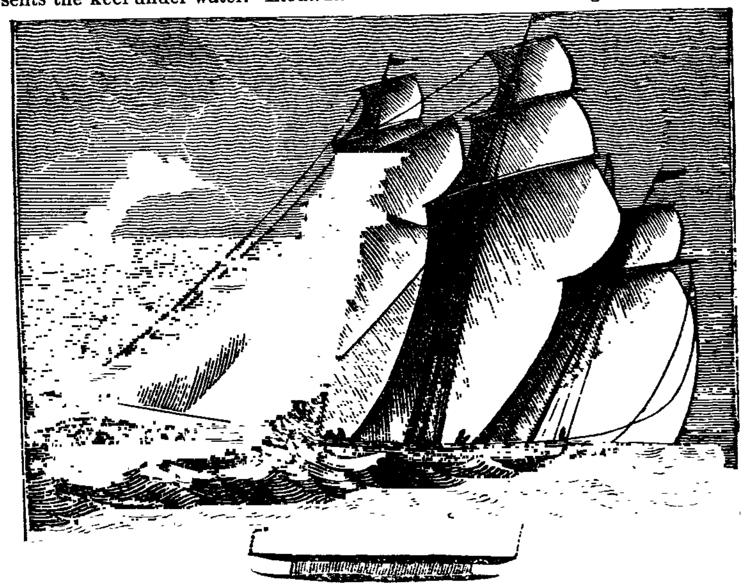
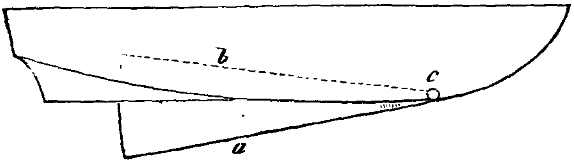


Fig. 1. *Fig.* 3. *Fig.* 2. *Fig.* 4.

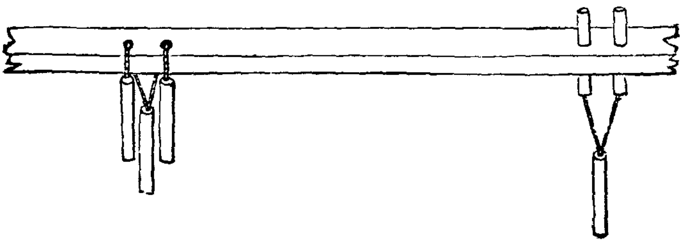
collection of sea weeds, which would impede the vessel's sailing. The sketch of a patent ballast-keeled lugger under a press of sail requires no elucidation, except to remark that the portion below the boundary line of the water represents the keel under water. Lieut. R. Shuldham's metallic sliding keel resembles



the common lee board in its shape, and is shown in the annexed diagram. *a* represents the sliding keel lowered down into the water; the dotted line *b* the



recess into which the keel is raised or deposited when not used; *c* the joint or fulcrum upon which it turns on being raised or lowered. One great objection to the plans of sliding keels is, their interfering with the keel and floor timbers, which must be cut through, thereby weakening the vessel; for instance, in Lieut. Shuldham's plan, the keel must be cut through longitudinally, or formed into two parts throughout nearly the whole length of the vessel, or at least through a portion as long as the sliding keel; they are also liable to be carried away, owing to the powerful leverage they afford to the water, and the difficulty of staying them sufficiently, without forming an obstruction to the speed of the vessel. The annexed engraving represents a simple plan for preserving the tholes or rowing pins of a boat, the loss of which is not only teasing, but often productive of serious inconvenience. Fixed tholes cannot be well used when



boats are to be hoisted in alongside, as they are subject to be broken; they are also often inconvenient in getting in water casks, as well as in many other cases. Hence pins which can be unshipped are preferred; these are often lost, and the want is not always discovered until it cannot be replaced; or it is not replaced without a loss of that time which is so valuable at sea. Very often, also, the delay of a minute is rendered inconvenient or even dangerous when the boat is dragging alongside by the painter in a heavy sea, and the vessel is either drifting or standing on. The drawing requires little explanation. By pulling at the lower pin the two upper ones are fixed at once, and on being unshipped they hang secure from loss, while the lower one serves as a spare thole should any be broken.

Before we close this article we must briefly notice Mr. Clint's ballasted masts for small sailing vessels, the object of which invention is to enable the boat constantly to retain an upright position, the mast alone yielding to the force of the wind. *Fig.* 1 is a section of the vessel, and *Fig.* 2 a plan of the same. *a* represents the hull of the vessel; *b* an oblong caisson of a semicircular section, suspended at each end upon pivots in the deck beams, at the point *c*. The mast is stepped in a trunk in this caisson, and secured by shrouds brought down to the sides of the caisson, and by a fore-stay proceeding to the stern of the vessel, and by a back-stay to the stern. The ballast is placed evenly in the bottom of the caisson. Among the advantages claimed by Mr. Clint for this construction are, first, perfect safety, as he considers it impossible a vessel can ever capsize. Secondly, the vessel being always upright, is constantly on what are termed her *lines*, and is always in *trim*, whereby she will sail faster and go better to windward; and lastly, that the ballast being suspended in air, is of more effect than

Fig. 1.

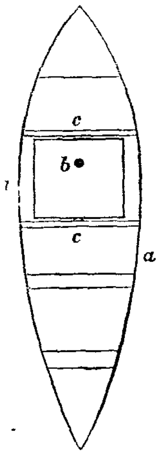
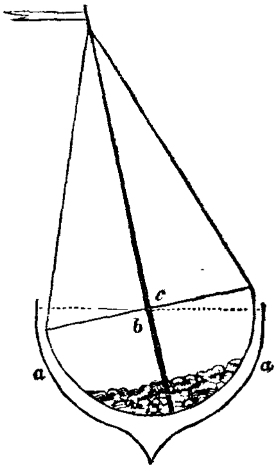


Fig. 2.



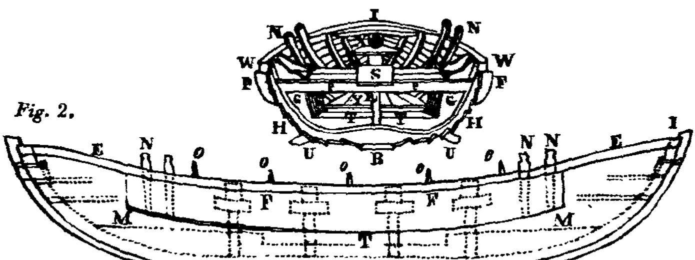
ballast placed in the bottom, which latter being identified with the vessel in the water, loses as much of its weight as is equivalent to its bulk of water, whilst the suspended ballast retaining its whole weight, a smaller quantity will be required to steady the mast, and the vessel itself requiring none, a great degree of buoyancy is obtained. Mr. Clint constructed a small vessel on this principle, and made a regular series of experiments during the summer of 1825, in presence of a number of scientific persons, and officers and seamen of the navy, some of whom accompanied him to Gravesend, when it blew fresh; and from the great satisfaction given by its performances, the Society of Arts voted Mr. Clint their large medal, or twenty guineas. This invention is only intended for such vessels as are not employed in carrying cargoes, of which class are revenue cutters, pleasure yachts, &c.; nor is it intended for vessels above seventy tons, which may have the box decked in.

BOAT (Life). A boat invented by Mr. Henry Greathead, of South Shields, for the purpose of preserving the lives of shipwrecked persons; and so well has it answered, and indeed, exceeded, every expectation in the most tremendous broken sea, that since its invention not fewer than 200 lives have been saved at the entrance of the Tyne alone, which otherwise must have been lost; and in no instance has it failed. The principle of this boat appears to have been suggested by the following simple facts: Take a prolate spheroid and divide it into quarters, in the line of its longer axis; each quarter is elliptical, and nearly resembles the half of a wooden bowl, having a curvature with projecting ends; this being thrown into the sea or broken water, cannot be upset, or lie with the bottom upwards. The length of the boat is 30 feet, the breadth 10 feet, the depth from the top of the gunwale to the lower part of the keel amidships, 3 feet 3 inches; from the gunwale to the platform within 2 feet 4 inches; from the top of the sterns (both ends being alike) to the horizontal line of the bottom of the keel 5 feet 9 inches. The sides from the under part of the gunwale along the whole length of the regular shear extending 21 feet 6 inches, are cased with layers of cork to the depth of 1 foot 4 inches downwards, and the thickness at the top 4 inches, projecting a little without the gunwale; the cork on the outside is secured with thin plate or slips of copper, and the boat is fastened with copper nails. The thwarts or seats are five in number, double banked, that is, two rowers sit upon each thwart, so that the boat can be rowed by ten oars. The side oars are short, with iron tholes and rope grommets, so that the rower can pull either way. The boat is steered by an oar at each end, and the steering oar is one-third longer than the side oars. The platform along the bottom is horizontal, the length of the midships, and elevated at the ends for the convenience of the steersman. The internal part of the boat next the sides, from the under part of the thwarts down to the platform, is cased with cork, the whole quantity of which affixed to the life-boat is nearly 7 cwt. The particular construction of this boat will be best understood by referring to the engraving, *Fig.* 1 representing a cross section of the boat, and *Fig.* 2 a longitudinal elevation. F F the outside coatings of cork; G G the inside cork fittings; H H the outside planks of the boat; I I the stems; K the keel;

N N timber heads; P the thwarts, or rowers' seats; R stanchion to support the thwart; S section of a gang-board, which crosses the thwarts and forms the passage from one end of the boat to the other. T the platform for the rowers' feet; U U the two bilge pieces, nearly level with the keel; W W the

Fig. 1.

Fig. 2.



gunwales; X X ring bolts for the headfast, one at each end; Y platform for the steersman; E E E the sheer or curve of the boat; L L the aprons, to strengthen the stems; M M the sheets, or places for passengers; O O O the tholes on which the oars are hung by grommets. After the value of the invention was attested by the presentation of a gold medallion to Mr. Greathead, by the Society of Arts, as also one by the Royal Humane Society, and various gratuities in money, parliament in 1802 unanimously voted him 1,200*l*. The Committee of Underwriters at Lloyd's Coffee House, having voted Mr. Greathead 100 guineas, appropriated 2000*l*. of their funds for the purpose of encouraging the building of life-boats on different parts of the coasts of the kingdom. Great numbers of these boats have since been constructed for all parts of our coasts, as well as for those of foreign nations. But as it most frequently happens that vessels are wrecked on coasts where there are no life-boats, or that from the darkness of the night or the strength of the wind and sea a life boat may not be able to reach the vessel in time to afford succour, it is highly desirable that all vessels should carry with them the means of safety for their crews; and accordingly numerous plans have been suggested of converting the ordinary boats of a ship into life-boats to meet these emergencies. Of these plans we select that of Captain Henry Gordon as amongst the most simple and efficacious, whilst it in nowise interferes with the ordinary services for which the boats may be required. It consists in attaching to the exterior of the boat a species of buoy, of a triangular form, which, whilst it adds greatly to the buoyancy of the boat, saves it from concussions, offers little obstruction to its progress, and can be attached or removed as occasion may require, with great facility and dispatch. *Fig.* 1 (page 195) shows the buoy; *Fig.* 2 an end view of the same; and *Fig.* 3 represents it fitted to a boat. The buoy is composed of fine Spanish cork, and consists of eight rows, each row being a foot longer than that immediately below it. Each row is constructed of pieces of cork 1 foot long, 6 inches wide, and about 1¼ inch thick, laid three thicknesses together, and then placed end to end till of the required length, (which in the drawing is represented at nine feet for the upper streak,) and then formed into one streak by lengths of split bamboo, laid on all four sides, and well sewed together by strong cord covered with shoemaker's wax. The different streaks are fastened together by four ropes, which are seized together between each streak; when used, the ends are drawn under the keel till the lower streak touches it, and then brought up over the side and fastened to the thwarts; the other triangle is in like manner drawn up under the boat's bottom on the opposite side and fastened. Two buoys to the scale of that shown in the engraving contain 14⅝ cubic feet of water; and if attached to a boat 28 feet long, and capable of containing twenty-four men, would leave a buoyancy of 718 lbs. for their support. Large boats, such as those capable

of containing 100 men, instead of a single large triangle on each side, should have three of 9 feet length each, by which means the same triangles might be made to serve boats of different sizes, by which the expenses of outfit would be materially reduced, and triangles of the above dimensions would also be more

Fig. 1.

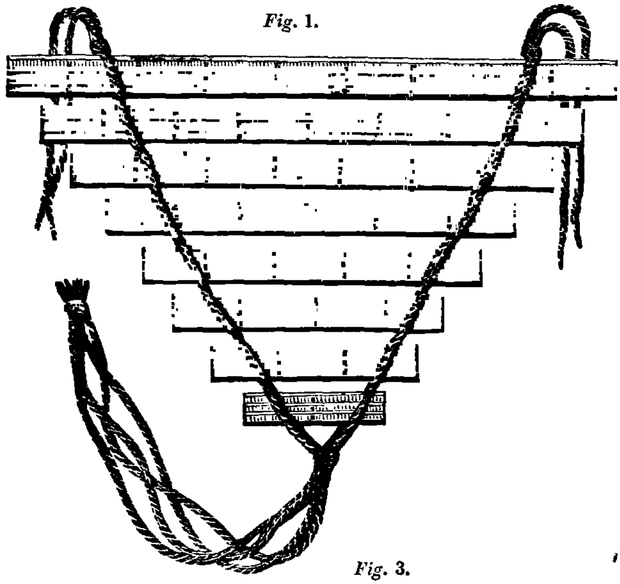
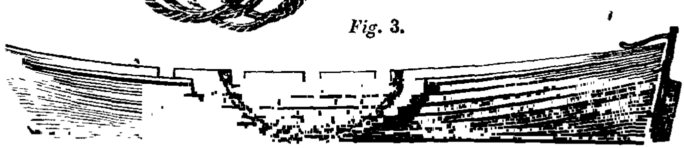


Fig. 2.

Fig. 3.



manageable, easier put on or taken off, and more easily stowed away than large ones. Thus the launch, rowing twenty-four oars, with seventy-five men on board, might be fitted in the following manner: the barge's triangle fixed amidships, the cutter's on the bow, and the jolly boat's on the quarter; the launch would then be rendered completely buoyant without any additional expense. The contrivance combines several advantages; it is extremely simple, and offers the best security under similar circumstances; it is so reasonable in its cost as to admit of every merchant vessel being supplied with it; and not being a fixture, it can be at any time removed, so as to be no additional weight when a boat is being hoisted in or out. It is particularly advantageous for the preventive service, to approach vessels and visit them when no other boat can; for a blow that would stave a boat, would not penetrate the triangle owing to its elasticity. At sea, also, it might take up a drowning man in a gale of wind, when no other boat could live.

BOILER, in its most extended sense, implies any vessel employed for producing the ebullition of liquids; thus the ordinary domestic pots and kettles, brewing and washing coppers, as well as all kinds of vessels used for heating liquids in various manufacturing operations, come under this denomination. Our business in this place is, however, the description of that important apparatus wherein is generated the source of that power which is regulated and applied by the steam engine; previous to which, we shall make a few observations on the requisite properties of steam boilers in general. The first and most important quality we consider to be *safety* from explosion, for unless this be attained, so as to render personal danger improbable, such boilers should not be used at all.

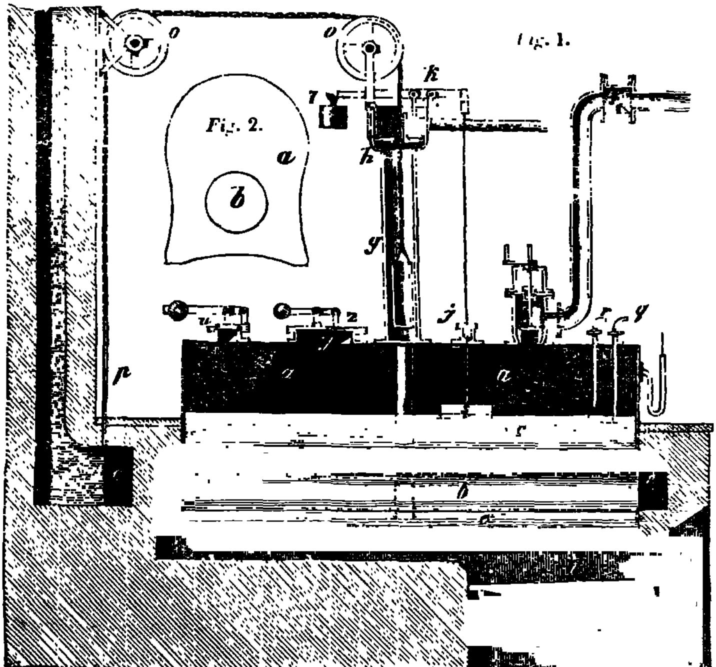
The next in importance is *effectiveness*, or that which will produce the required quantity of steam by the consumption of the least quantity of fuel. *Cheapness* in the cost of construction, and durability in the wear, may be ranked as the third requisite. The fourth is, perhaps, *convenience*, or that which can be worked with the utmost facility, that will require the least personal attention, and will occupy the least space. That boiler which combines the four qualities just mentioned, and possesses each in the most eminent degree, may be deemed a perfect one. The materials principally used at present for the construction of boilers are iron and copper, though boilers have been made of wood and stone. In those formed of wood the furnace was of necessity placed internally, surrounded by the water; and as wood is an extremely bad conductor of heat, but little loss of it was sustained by radiation therefrom, while a considerable economy of fuel was consequently effected. The cost of such was also small, compared to those of metal; they were introduced in America by Chancellor Livingstone and Mr Anderson. Boilers of stone were introduced by Mr. Brindley, who, in 1756, erected a steam engine near Newcastle-under-Lyne, with a boiler of this description. It was composed of brick and stone firmly cemented together, and the water was heated by iron flues. The material of which a boiler is constructed is of more consequence, in an economical point of view, than is usually supposed, as the heat cannot be communicated to the water without being first transmitted through the substance of which it is formed. M. Despretz, who made a series of very accurate experiments to determine the comparative power of different substances for conducting heat, obtained the following results:—

Gold	1000.0
Silver	973.0
Platina	981.0
Copper	898.2
Iron	374.3
Zinc	363.0
Tin	303.9
Lead	179.6
Marble	23.6
Porcelain	12.2
Fire bricks	11.4

The conducting power of copper being thus more than double that of iron, offers very great advantages; but there are other considerations to be entered into before determining to which the preference is due, especially their comparative cohesive strength and cost. According to some experiments the copper was found to be the strongest, but that was probably owing to the iron being of inferior quality, as most philosophers have agreed in attributing superior cohesive strength to iron. Notwithstanding this circumstance, from the greater uniformity of the texture of sheet copper over that of iron, manufacturers usually construct copper boilers of thinner plates than those of iron, that have to withstand the same pressure of steam. Experience has, we believe, established this as a rule, probably from observing that when a copper boiler bursts, it only *tears* open, while a boiler of wrought iron plates is often blown to pieces. The cost of copper is, however, four times that of iron; but if it be admitted that the quantity of heat passing through iron in a given time can be doubled in copper, it follows that a copper boiler having only half the superficies of one of iron, exposed to the action of the fire, will be adequate to the generation of the same quantity or force of steam. This circumstance, therefore, greatly reduces the weight of the copper boiler, and, consequently, its first cost is made to approximate more to that of the iron boiler of double the size. Increased strength is likewise acquired by the reduced dimensions of the copper boiler, so as to permit of a decrease of the pre-supposed thickness of metal; and thus the greatly enhanced price per pound of a copper boiler over that of an iron one, which alarms many steam engine proprietors from ordering them, is very much disproportioned to the cost of the entire vessel. When an iron boiler is worn out, the old metal is scarcely worth the expense of removal; but when one of copper is decayed, the old

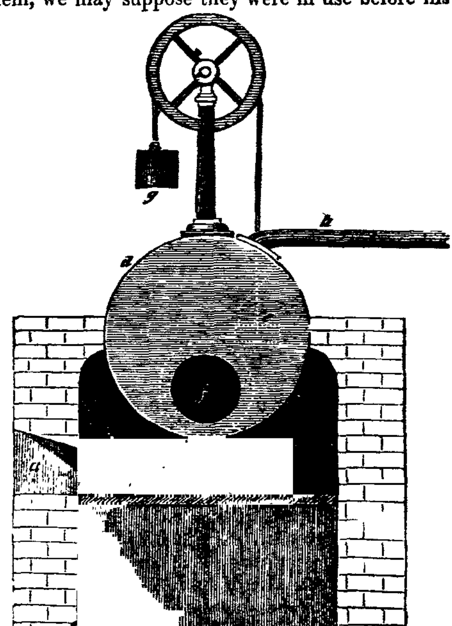
metal is worth three-fourths of its original cost. These considerations, together with the increased safety and reduced bulk of copper boilers, inclines us to believe that in a course of years their use will be found more economical than those of iron. In the construction of boilers of the ordinary form (that is, such as consist of a capacious single chamber), the bottom surface should be of sufficient extent to be capable of absorbing as much heat as will be necessary to produce the required quantity of steam, what little heat may be given out laterally serving to prevent condensation in the upper part of the vessel; and the smoke, before it enters the chimney, should be robbed as much as possible of its heat by being brought into contact with the conduit pipe, by which the boiler is supplied with cold water. It has been stated by a scientific authority that there is a considerable waste of fuel in producing steam by intensity of heat upon a small surface, and that the application of a moderate heat (800° Fahr.) is far more economical. A cubic foot of water converted into steam per hour was reckoned by Mr. Watt as equivalent to one horse's power, who observed that this quantity of steam could be raised per hour by 8 feet of surface of boiler and flue, in a judiciously constructed furnace. In practice, it is usual to allow from 4 to 5 feet of *bottom* surface of boiler to raise 1 cubic foot of water into steam per hour. It is considered essential that a boiler should contain four or five times as much water as it boils off per hour; and it is obvious that it should have a space above the water capable of containing as much steam as will supply the engine at each stroke, without materially diminishing its elastic force. For this purpose, the steam room (or space above the water) should hold a volume equal to the supply of eight or ten strokes of the engine: in large engines it is not unusual to employ two, three, or more boilers, to supply them with steam; one of them being reserved for use, in case of repairs being required to the others. In fact, a spare boiler should be provided wherever stoppages are of serious importance in a concern. The strength of low-pressure boilers should be twice the regulated pressure on the safety-valve; but high-pressure boilers should be proved to at least three times their working pressure. Upon the form of boilers much of their strength and their efficacy in the generation of steam depend. The earliest boilers employed for generating steam, and applied as a motive force, with which we are acquainted, were either globular or hemispherical, with flat or concave bottoms; and many of these are still in use for the supply of high-pressure engines. In situations where fuel is so abundant as to render needless any economy of it, they may continue to be used with advantage, as their form adapts them to withstand steam of great elastic force. The waste of fuel caused by them, elsewhere, led to a very general substitution of boilers of an oblong form; and those known by the term of "waggon boilers," from their shape, formed one of the many improvements of the steam engine introduced by Watt. A longitudinal section of a boiler of this kind is represented by *Fig.* 1 in the subjoined engraving, fitted up with all the appendages now generally applied, and set in a furnace of the usual construction. *a a a* is the boiler, having a cylindrical return flue *b* throughout its length; the form of these parts will be best understood by considering them with reference to *Fig.* 2, which shows the figure of the boiler in its cross section, *b* being the return flue; this portion of the boiler should be always placed near to the bottom, and be constantly kept covered with the water, as seen at *c* in the drawing. The flame and smoke from the furnace *d* first passes under the boiler, then returns through the flue *b* to the front, where the current is divided, and passing to the right and left through lateral flues in the brickwork (one of which is brought into view at *e e*) before it enters the chimney *f f*. The water is supplied to the boiler by the feed-pipe *g*, which is made to contain a column of water equal to the amount of pressure in the boiler. On the top of this pipe is a cistern *h*; *i* is a float, made of stone, suspended by a wire passing through a stuffing-box *j*, which is attached to one extremity of a lever, whose fulcrum is at *k*, a weight *l* being suspended to the extremity of the other arm of the lever sufficient to counterbalance the difference between the specific gravity of the stone and the water, causing the former to lie on the surface of the latter. By this arrangement, when the water sinks below the proper level in the boiler, the stone float descends with it, causing the attached wire to operate upon the

lever above, and lift the valve shown in the cistern *h*, which then affords a fresh supply of water. The feed pipe likewise contains an iron bucket, hung by a chain that passes over two pulleys *o o;* the other end of the chain is attached to a plate of iron *p*, called the damper, which is used to enlarge or contract, and,



when required, entirely close the throat of the chimney. By this contrivance, when the steam in the boiler is urged to too great an extent, its pressure forces the water in the feed pipe upwards, thereby raising the bucket *m*, and causing its counterbalance, the damper, to descend in the throat of the chimney, and reduce the intensity of the fire. At *q* and *r* are two guage-cocks, by which the proper height of the water in the boiler may be always ascertained. If *q* discharges water, and *r* steam, the water is at the proper height; if both cocks discharge water, it is above its proper height; and if both discharge steam, it is below its proper height. This latter circumstance, which can only take place by the defective action of the last described apparatus, is of serious moment, and requires an immediate remedy; the most safe is, in our opinion, the reduction of the fire, by stopping up, by the readiest means at hand, all access of air to the grate, after which, attention may be paid with confidence to removing the cause of the defect. For the purpose of showing at all times the pressure acting upon the boiler, a steam-guage is employed. This is usually made of an iron tube, bent into the form represented, one end communicating with the steam-room of the boiler, and the other open to the atmosphere. This tube is partly filled with mercury, and into the externally open end is put a slight rod of wood, which floats perpendicularly in the mercury, and shows by its altitude, on a divided scale of inches affixed to that leg of the tube, the pressure of the steam. If the steam raises the mercury or rod one inch, it proves that the pressure is one half pound per square inch on the internal surface of the boiler, tending to burst it; for if the section of the bore of the pipe was just one inch, the pressure would be supporting one cubic inch of mercury, which will be found to weigh nearly half a pound; therefore, for every two inches rise, one pound pressure

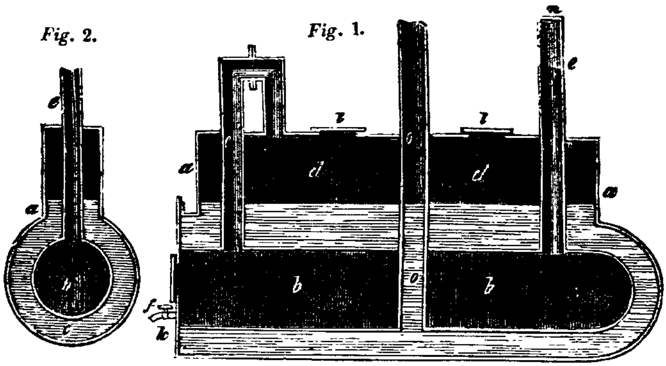
may be reckoned; and as condensing engines seldom work with more than three or four pounds pressure upon the inch, the scale need not be longer than eight or nine inches For preventing the pressure becoming greater than the boiler is calculated to sustain without incurring danger, a safety-valve *u* is provided. This is usually a circular piece of metal, with a conical periphery ground to fit into a conical seat, and kept there by the pressure of a lever, loaded with a determinate weight, that will not suffer it to rise until the steam has acquired an excess of force above that required for working the engine, or would endanger the bursting of the boiler. In large boilers, especially those in steam boats, it is usual to have another safety valve, inclosed in a box under lock, the key being kept by the chief manager, to prevent the possibility of improper interference with it, by ignorant or imprudent persons: by the neglect of which precaution many serious accidents have occurred. The steam which escapes from safety valves is generally conducted by a pipe from the valve boxes into the chimney. At *v v* is the steam-pipe by which the engine is supplied, the quantity being regulated by a throttle-valve at *w*, and a screw-down valve at *x*. For the purpose of cleaning out or examining the condition of the boiler, a circular or oval hole *y* is made sufficiently large to admit a man to pass through, and therefore called the man-hole. It is covered by a strong plate of iron bolted down, in which plate is usually fitted the atmospheric or vacuum safety valve *z*, which opens inwards by the pressure of the atmosphere, preventing the latter force from injuring the boiler, should a vacuum be formed by condensation within. A cock and pipe leading from the bottom of the boiler is employed for discharging it of its contents. Next to the waggon-shaped boilers of Watt, those of a long cylindrical form have been the most extensively employed, especially for high-pressure engines, on account of their superior strength; besides as affording a considerable surface for the direct action of the fire and heated gases. They are usually known in this country by the term "Trevithick boilers," from the supposition that Mr. Trevithick was the inventor. We, however, observe, that Mr. Oliver Evans, of America, describes them as being used by him in his high-pressure engine, prior to the patents of Mr. Trevithick, and as Mr. Evans does not claim them, we may suppose they were in use before his time. Cylindrical boilers are frequently made of a great length, ten, twelve, or more times their diameter, and are preferable of such proportions, where their situation will admit of it, for the reasons before mentioned. In this country their extremities are usually made hemispherical; but in America the ends are usually closed by flanged disks of great thickness, on account, we suppose, of the greater facility of construction by ordinary workmen. These boilers are generally provided with an internal flue, through which the heated air and flames, after traversing the length of the under side of the boiler, pass before entering the chimney. The annexed diagram represents a transverse section of a small high-pressure cylindrical boiler, as manufactured by Mr. Saunders, late of Sheffield, but now of New York, U.S. The furnace



door is at *a*; *b* the furnace; *c* the ash pit; *d* the boiler; *e* the stone float (shown by dotted lines), for regulating the supply of water, by means of the counterpoise *g*; *f* is the internal flue, which returns the flame and heated air through the boiler; *h* the steam pipe leading to the engine.

The boiler figured in the annexed cut, is of a cylindrical figure in the lower part, but combines some peculiarities that are deserving of notice. It is a patented arrangement by Messrs. Horton and Fisher, who are large boiler manufacturers, near Birmingham. The object of it is to form a reservoir of steam within the boiler, surrounded by the hot water, in order that the pressure of the steam may not be reduced by radiation, which the inventors presume to be the case in a greater degree in boilers of the ordinary construction. *Fig.* 1

Fig. 2. *Fig.* 1.



represents a longitudinal section of the boiler, and *Fig.* 2 a transverse section of the same: the letters of reference apply to similar parts in each view. *a a a* shows the external form around which the furnace and flues are to be constructed; *b b b* is the internal vessel or reservoir, for containing the steam generated, surrounded by the water which is supplied by the tube *o o* from another reservoir placed above, but not introduced into the drawing. The heat having caused the steam to fill the upper part of the boiler *d*, it passes thence through the bent tube *c* into the steam reservoir *b* below, from whence it is conducted to the engine by the steam pipe *e*, the top of which *n* is designed for the situation of the safety valve. At *f* is a cock for drawing off whatever water may be condensed in the steam chamber, and at *k* may be placed another for discharging the boiler. At *l l* are man-holes for gaining access into the interior. We do not ourselves perceive how the intention of the patentees to make the internal vessel *b b* a store of high steam for the supply of the engine, can be effected by this arrangement, for the hottest steam will be rather disposed to obey the laws of nature, and *ascend* into the upper vessel through the bent tube, than *descend* through the same to the lower vessel, according to the desire of the contrivers. It must, however, be admitted that there is a considerable degree of originality in this boiler, and it may prove a useful and effective generator of steam.

In 1803, Mr. Woolf patented his boiler, which has obtained much deserved celebrity. It has been for many years very extensively and successfully employed in Cornwall, for the production of steam for the large mining engines there. We have already observed that the long cylindrical boilers possess great advantages over those of a cubiform or rotund figure. To increase their safety, and their capability of producing steam at very high pressures, Mr. Woolf greatly extended the principle of the cylindrical form. One of the most simple of this gentleman's construction consists of eight tubes of cast iron (of six or more inches in diameter), connected to each other by a bent tube at their extremities, with communications to a larger cylinder above them, employed as a reservoir for the steam. The furnace is divided by a wall longitudinally into two parts, and the eight tubes are fixed horizontally across both these. The fuel chamber is at one extremity of one of the divisions, and arched above the two first tubes

so as to reverberate the flames and heated vapours, which then pass under the third tube, over the fourth, under the fifth, over the sixth, under the seventh, and partly over and partly under the eighth tube, when the flue turns into the second division of the furnace, on the other side of the wall, built under, and in the direction of, the large steam cylinder before mentioned. Passing now under the seventh cylinder, the course of the flue is over the sixth, under the fifth, over the fourth, under the third, over the second, and partly over and partly under the first, when it enters the chimney. To produce this long serpentine reverberation, the upper and under side of the brick-work is formed in arches, alternately reversed, their extremities abutting against the tubes, covering about a sixth part of their circumferences, but exposing the rest to the action of the current of heated matters from the fire. Each of the tubes is provided with a flanged disk at one end, fastened on by screw bolts, that they may be easily removed, and the tubes cleaned out at pleasure from sediment and incrustations. The water carried off by evaporation is replaced by the usual means of a force pump, and the steam generated is conducted to the engine or other object, by a tube connected to the steam reservoir. "It may not be improper," says Mr. Woolf, "to call the attention of those who may hereafter wish to construct such apparatus, to one circumstance: namely, that in every case, the tubes composing the boiler should be so combined and arranged, and the furnace so constructed, as to make the fire, the flame, and the heated air, to act around, over, and among, the tubes, embracing the largest possible quantity of their surface. It must be obvious to any one that the tubes may be made of any kind of metal; but I prefer cast iron as the most convenient. The size of the tubes may be varied; but in every case care should be taken not to make their diameter too great; and it must be remembered, that the larger the diameter of any single tube in such a boiler, the stronger it must be made in proportion, to enable it to bear the same expansive force as the smaller cylinders." Mr. Woolf also directs that the lower tubes should be always kept *filled*, and the upper, or steam cylinders, half filled with water, that is, as high as the fire is allowed to reach, and that in no case the water ought to be allowed to get so low as not to keep full the branches which join the lower tubes to the upper cylinder.

The annexed engraving exhibits an arrangement of parts combining the leading features of several previous inventions, and was patented by Mr. Thomas Tippet, of Gwennap, in Cornwall, in 1828. *Fig.* 1 represents an end view, and

Fig 1.

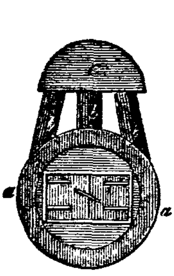


Fig. 2.

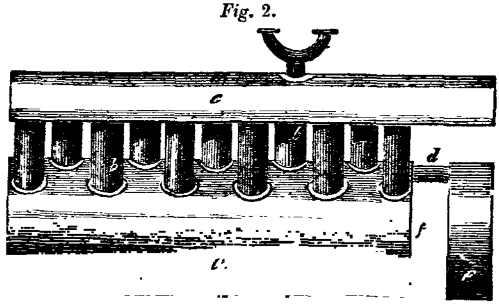


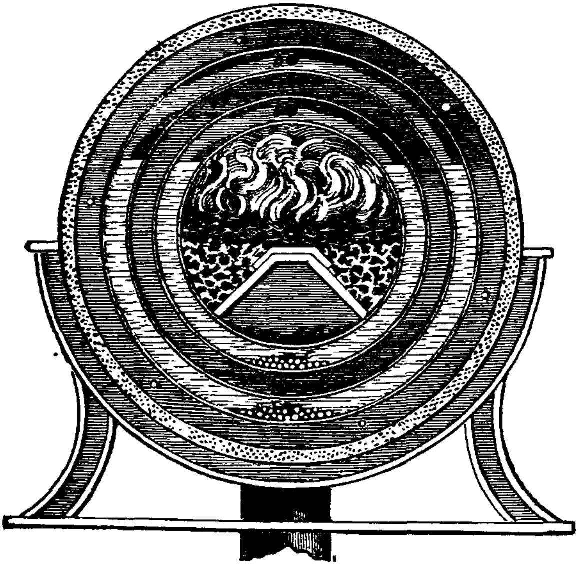
Fig. 2 a side view of the boiler; the same letters of reference in each indicating similar parts. *a* is a large cylindrical boiler, containing an internal cylinder, which constitutes the fire place and principal flue. From the external cylinder, which contains water, proceed three rows of open vertical pipes *b b b*, which support a semi-cylindrical steam vessel *c*. At the farthest extremity of the cylinder *a* there proceeds horizontally a short open pipe *d*, communicating with a small supplementary boiler, which is a cylinder of the same area as *a*, but very short. This boiler is built in a furnace, in which the flues are so arranged that the heated air, in passing out at the end *f* of the furnace flue, shall impinge against the flat side of the supplementary boiler; the flue thence proceeds upwards, and along the underneath flat side of the semi-cylindrical vessel,

between the vertical tubes to the front of the boiler, where it descends, passing under the bottom of the latter, then round the back of the supplementary boiler, and over the top of the semi-cylinder to the chimney, which is in front, nearly over the furnace doors.

An ingenious attempt to expose water in thin sheets over an extended surface of metal, was made by Mr. John M'Curdy, from the United States, who patented it in this country. It consisted of a series of cylinders, with spherical ends, arranged horizontally like retorts, in a pyramidal form, in a furnace, so as to cause the heat as much as possible to impinge against their surfaces, in its ascent amongst them to the flue above. Each of these cylinders contained within it another cylinder, of so much less diameter than the outer, as to leave between them throughout a very narrow space, the uniformity of which space was preserved by coiling a spiral band upon the outside of the inner cylinder, or other suitable contrivance. These latter cylinders were hermetically closed at each of their ends, and were placed inside the former to produce between them hollow cylindrical sheets of water. The water was forced into one of the lower cylinders, and made, by the action of the pump, to circulate through the others of the series. By this arrangement of disposing the water in thin sheets, it was presumed that steam of a very high pressure would be generated with extraordinary rapidity. We have, however, never been informed of the cause of this boiler not having been brought into practical operation, and are therefore left to conjecture that it was probably owing to the great expense of construction; the liability to deposits and incrustations in the narrow spaces between the internal and external cylinders; the difficulty of cleansing them; and, by the neglect of the latter operation, causing an irregular generation of steam, the heating red hot the incrusted parts, and, as a consequence, the blowing out of the water, and the rapid destruction of the metal. To these causes may be added the waste of fuel by the shortness of the flue. The contrivance is, nevertheless, not devoid of merit, and may afford a useful hint to succeeding inventors. The superior strength and safety of boilers made of small tubes have within the last few years led to their introduction in almost every possible variety of form, a great many of which have been the subjects of unproductive patents. Those which possess the most distinct character from each other, and have been more or less brought into public use, we shall proceed to notice.

The first we shall describe is the invention of Mr. W. H. James, patented in 1823. It consisted of a series of annular tubes of equal capacity and diameter, placed side by side, and bolted together, so as to form by their union a long cylindrical boiler, in the centre of which, at one end, the fire-place was situated. The tubes were made of the toughest wrought iron, three sixteenths of an inch thick; and being of only one inch in diameter, they were capable, as was proved, of sustaining a pressure of several thousand pounds per inch. In some of these boilers, the tubes were made square in their transverse section, consequently, when their flat sides were placed together as described, there were no open spaces between them; and the annular tubes were connected together by means of long bolts passing through the end-plates of the cylinder, where they were screwed up firmly by nuts on the outside. Communications from tube to tube were made by making two perforations in them lengthways of the cylinder; one on the upper side, for the free passage of the steam, and one on the lower, for the flow of the water. When it was desired to construct a boiler of greater power in a compact form, to adapt it more particularly to locomotion, Mr. James preferred making two concentric cylinders, each composed of a series of annular tubes, like those described, and as delineated in the annexed diagram, which exhibits a transverse section of such a boiler. The annular tubes are distinguished by the water drawn therein. The upper perforations or steam passages are shown at *b b*, and the lower, or water passages, at *c c*. The water was maintained at the desired level by the action of a float, in an adjoining vessel, not shown in the figure. The furnace bars formed two inclined planes, as shewn, at one end of the cylinders, and the flue descended at the other end. These latter parts were made so as to be easily detached at pleasure. The entire boiler turned upon an axis, and rested upon

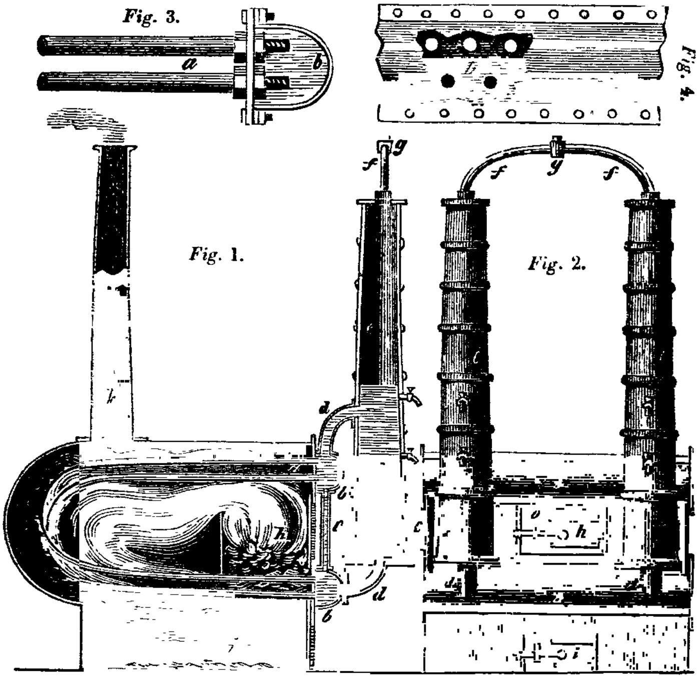
rollers, fixed in a circular stand; every tube was furnished with some shot, mixed with angular pieces of metal, so that when it was desired to cleanse the boiler of deposit, the furnace and chimney tube were drawn out, the connecting pipes unscrewed, when the cylinder was turned round by a winch, in



the manner of the common scouring barrel, used for brightening metallic articles. To prevent the loss of heat by radiation, the boiler was surrounded by a double case, the spaces between which were filled up with a mixture of clay and charcoal. We have repeatedly seen a boiler of Mr. James's construction, on the principle of the last described, but consisting of only one cylinder of annular tubes, 3 feet 6 inches long, and 20 inches diameter, effectively working a very small high pressure engine, (having only a 3 inch piston of 12 inch stroke,) up to three horses' power. This boiler had circular tubes, and each annulus was made out of two semicircular pieces, connected at their extremities to an upper and a lower transverse horizontal tube, the length of the cylinder; the upper one forming the principal and the connecting steam tube, and the lower one the water tube. Into these horizontal tubes, conical perforations were drilled, to receive the extremities of the semicircular tubes to which they were united, steam and water tight, by means of bolts and rivetted keys. However firm this mode of uniting appeared to the eye, and however accurate the workmanship, when the fire came to act upon the joints they often became leaky, and were the source of great trouble and inconvenience. Since the period alluded to, Mr. James has invented another boiler, to which he gives the preference, and will be described under the article Steam. Before, however, we quit this part of the subject, we would draw the reader's attention to the circumstance of the steam chambers in Mr. James's boiler, as shewn in the preceding engraving, by which it is evident that the surfaces of the water are pressed upon by the steam, and that the latter derives an increase of heat and of elasticity subsequently to its formation, by the action of the most intense part of the fire; consequently it would appear that this arrangement is eminently calculated to prevent the water rising, or being forced over into the engine; an inconvenience which had been experienced in most boilers made of small tubes. Although the inconvenience never occurred in Mr. James's boilers whilst the fire was kept steady, the supply of water regular, and the tubes clean; yet from the neglect

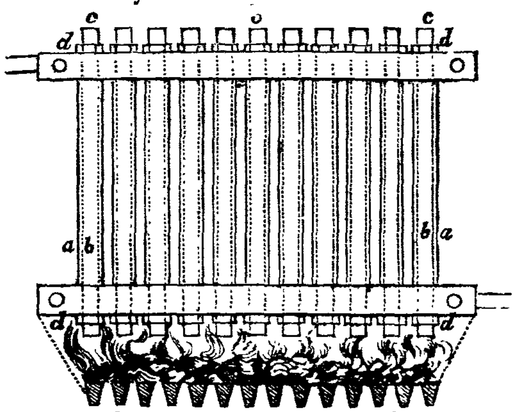
or failure of some one of these conditions, the water did occasionally come over. The observations we have been enabled to make upon these facts, incline us to the opinion that it would be better not to make boilers of tubes of a less diameter than two inches; because the much larger body of water such contain are not so suddenly and violently affected by ordinary variations of temperature occasioned by unskilful firing, or by the irregular supply of water; nor are the tubes so liable to become choked, as the joints can be made with greater accuracy without filling up the water or steam way, to the danger of the tubes becoming red-hot, and the destruction of the boiler. Tubes of two inches can be much more easily cleansed; and as respects safety, it is scarcely possible to burst them, if only a quarter of an inch thick, by any pressure of steam that can be beneficially applied.

The contrivance we shall next notice is the invention of Mr. Goldsworthy Gurney, a gentleman of the medical profession, but more generally known to the public by his persevering attempts for the establishment of steam carriages on the common road; and the boiler we shall describe is especially designed for



that purpose. *Fig.* 1 shows a vertical section of the boiler. *Fig.* 2, an external end view of the same. *Fig.* 3, the manner in which the series of pipes composing the boiler are fixed, and open into horizontal chambers. *Fig.* 4, a portion of one of the horizontal chambers, partly broken away to exhibit the apertures of the pipes, and their arrangement. The same letters on each figure refer to corresponding parts. In the section *Fig.* 1 the semi-elliptical form in which the pipes are bent, and the manner in which they respectively cross each other, is seen; the ends of these pipes have screw threads on the outside, to receive nuts, which secure them to the horizontal chambers *b*, as shown in *Fig.* 3; a packing composed of pounded asbestos, mixed with red lead and litharge, in about equal parts, is interposed between the nuts and the end plate, applied in hollow washers of a saucer-like form, which it is said makes perfectly steam, water-tight, as well as fire-proof joints. The chambers *b* have

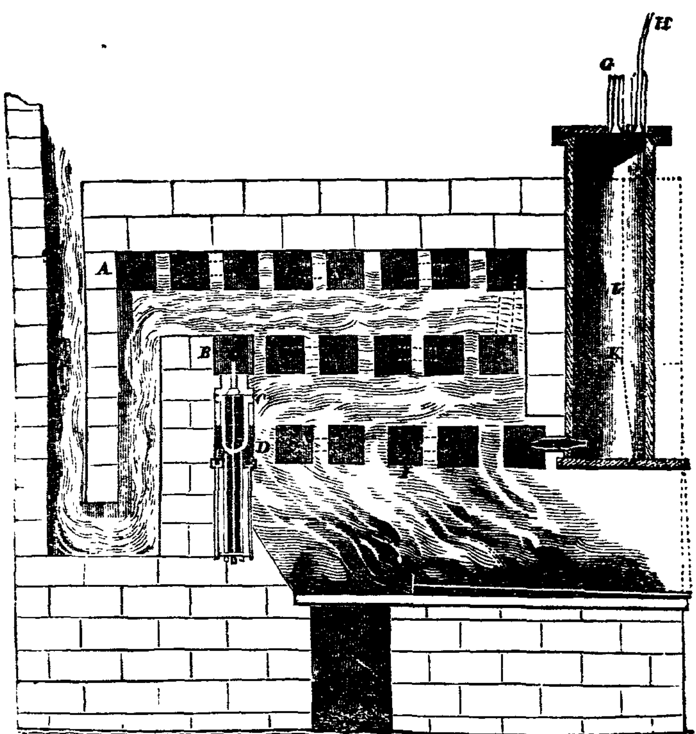
direct communication one with another, by means of the vertical pipes *c*; *d d*, are two bent tubes, leading from *b b* into the steam vessels or "separators" *e e* (as Mr. Gurney calls them.) From thirty to fifty, (according to the size of the apparatus) of the small pipes *a*, are arranged in the manner shown in *Figs.* 1 and 4, in which the fuel is placed as at *h*, the heated air and flames being directed by a bridge *i*, to take the course delineated before entering the chimney *k*; but a considerable portion of the heat passes freely between and round about the pipes, the whole of them being exposed to the powerful effects of a furnace so circumstanced; *o* is the furnace door, and *i* the ash-pit. During the working of the engine, the steam chambers *e* are by the usual means kept supplied with water up to the level shewn, which being higher than the pipes in the furnace, the latter are always kept full of water, as judiciously recommended by Woolf in his specification, quoted in the preceding part of this article. The steam generated in the small pipes ascends by its superior levity through the water in the steam vessels *e*, or it may be, transmits its caloric to other particles of water, which escape at the surface of the fluid in the form of vapour, which passes off through the branches *f f* into a common pipe *g*, that leads to the engine. In fixed engines the iron casing represented as surrounding the boiler is dispensed with, the apparatus being set in the usual manner in brick-work. To obviate a common objection to tubular boilers, of their becoming choked with a deposition of earthy matter, Mr. Gurney purposes to clean them out when they become foul, by the following chemical treatment. If the tubes are of *iron*, one part of muriatic acid, with 100 parts of water, are to be left in the boiler, a sufficient time to dissolve the incrustations; if of *copper*, the following solution is to be used in a similar way, one pound of common salt, half a pound of sulphuric acid, in four gallons of water. To expedite the operation of cleansing, a small fire may be made in the boiler, and the steam be employed to blow the contents out of the tubes. One of the most prominent advantages attending the use of this boiler, is the great facility with which repairs are executed; when a tube is injured or burned, the removal of it or the substitution of a new one are only the work of an hour. Like other tubular boilers, it is safe from the effects of rupture; but the "separator" being in fact a steam reservoir, that part is as liable to explosion as other boilers of the same capacity and thickness of metal. The small tubes exposed to the fire, if always kept full of water, are not likely to be soon burned out. The merit of this arrangement is however, due to Mr. Woolf, (see page 201,) and were Mr. Gurney's steam reservoirs defended like that gentleman's, from the cooling influence of the atmosphere, the effect of their contents upon the engine would be improved.



The annexed diagram is explanatory of a boiler which has been employed for the generation of steam in the locomotive carriage of Messrs. Summers and Ogle, who have taken out a patent for it. It consists of a series of tubes, placed vertically, with a flue passing up the centre of each; *a a a* represents the external tubes containing the water and steam; *b b b* the interior tubes or flues, for the passage of a portion of the heated air, &c., the remainder passing off between the exterior tubes; and thus the water of the boiler disposed in thin hollow cylinders is continually exposed to an extensive surface of heated metal on both sides. *c c c* are the ends of the internal tubes passing through the screwed nuts *d d d* at the top, and *e e e* at the bottom, and by

which both the exterior and interior tubes are secured in their places. The water is supplied to the boiler through the pipe *f*, by a force pump; and the steam when generated, passes off to the engine, by the pipe *i*. Although the heated matters from the fire have but a short passage to the chimney, it is obvious that the obstruction to the current formed by so many tubes crowded together must be considerable, and cause a great portion of the heat to be absorbed, it being, as it were, wire-drawn. Economy of fuel is, however, not a matter of such important consideration in a steam carriage, as in fixed engines; there being in the present infant state of locomotion, on the common road, no competition. It is obvious that the different parts of this boiler can be put together with facility, and that a defective tube can be instantly removed, and a sound one substituted, by simply unscrewing the interior flue or tube. The manufacture, however, requires the utmost exactness, especially in making all the tubes of precisely the same length, and the other parts corresponding with each other of uniform dimensions; otherwise a source of imperfection would arise, from the longer tubes preventing the shorter ones from being screwed sufficiently close to render them steam-tight.

Although the inventions of Mr. Jacob Perkins (who has distinguished himself by numerous ingenious attempts to generate and work steam at pressures far beyond that of any other experimentalist or engineer,) have not been attended with that success which the public were led to believe, many of his arrangements possess considerable merit, and ought to have a place in this work. We allude in particular to his having brought steam of enormous pressure under the most perfect control. The annexed diagram is explanatory of a boiler

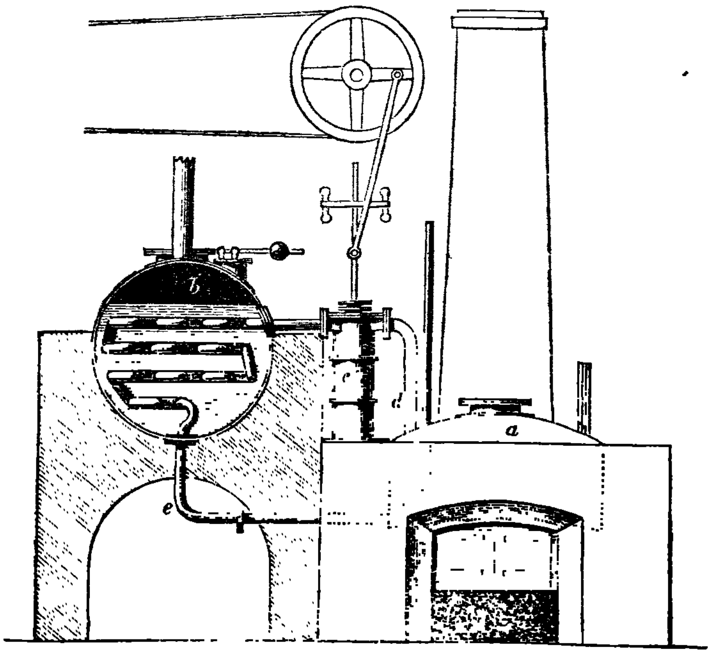


employed by Mr. Perkins, which we saw working a small engine on the high pressure and expansion principle, calculated by him at 30 horses' power. A series of cast-iron bars, 5 inches square, perforated throughout longitudinally,

with 1¼ inch circular holes, were arranged in three tiers, A, B, and D, across a furnace, of sufficient length to come through the opposite walls, where their extremities were connected together in a peculiar manner, so as to form one continuous vessel. By the operation of a forcing pump water was continually injected under the pressure of a heavily loaded valve into the two upper tiers of tubes, so as to keep them always full; the third or lowest tier of tubes contained no water, and were to be kept at a temperature of about 1000° Fahrenheit. At each stroke of the engine, a certain quantity of the water contained in the two upper tiers, (supposed to have acquired a temperature of 700° or 800°,) was discharged into a valve box at C, communicating with the lowest tier of tubes D, wherein it flashed into steam, and passing successively through those tubes, exposed to the intensity of the fire, it was received into a steam chamber L for the supply of the engine. The object of the inventor in introducing such great masses of metal into his apparatus is not very apparent, unless it be the prevention of sudden and great variations of temperature in the tubes, which perhaps could not otherwise be effected, as the body of water they contain is too small to maintain much uniformity of heat, and Mr. Perkins must be well aware that the perfect safety of such generators is not increased by forming them of a square figure instead of circular.

To obviate the destructive effects of the direct action of the fire upon the substance of which a boiler is constructed, and by which action the liability to rupture is increased, a great variety of plans have been projected. Three of these plans, which appear to be deserving the attention of the reader, we shall subjoin.

The first is the invention of Mr. Aaron Manby, of Horsely, near Tipton, in Staffordshire, for which he had a patent in the year 1821. It is well known that oil and other fatty matters are capable of being raised in temperature far above that of boiling water, without undergoing decomposition; this property in oil having never before been applied to the working of a steam engine, formed the groundwork of Mr. Manby's patent. The construction of his apparatus is explained by the annexed diagram; where *a* represents an oblong boiler, sup-



posed to be set in brickwork, over a fire-place of the usual construction. This vessel is to contain the oil, which is to be heated to about 300° Fahrenheit. The vessel above *b* is a strong cylinder, containing the water to be converted into steam, inside of which is fixed a system of pipes, connected into one continuous line; through these pipes the oil is made to flow by the action of a pump at *c*, (worked by the engine, or other first mover,) which raises it by the pipe *d*, and discharges again into the boiler by the pipe *e*. The heated oil in its passage through the pipes elevates the temperature of the surrounding water, and converts it into steam of several atmospheres' pressure. The patentee states, that by this apparatus steam of very high pressure may be generated without the possibility of danger, and that a smaller quantity of fuel is consumed than when the fire operates in immediate contact with the water vessel. In what manner, however, this economy is effected is not very apparent; and although the danger of explosion in the steam vessel is considerably lessened, the liability to accidental conflagration is so far increased by the contiguity of the furnace to such an inflammable substance as oil, (which was liable also to become thick and glutinous) as to render it imprudent to use the apparatus in buildings that are not fire-proof.

The second invention we have to notice is that of Dr. Ernst Alban, a physician of Rostock, in Germany, a patent for which was obtained in this country in 1825. The heating medium is, in this case, such a mixture of tin and lead as will remain in a fused state at the temperature required for the steam, which is generated in small vertical tubes suspended in the bath of liquid metal. The subjoined diagrams exhibit two baths of this kind connected together, in each of which are deposited eight generating tubes. *Fig.* 1 shows

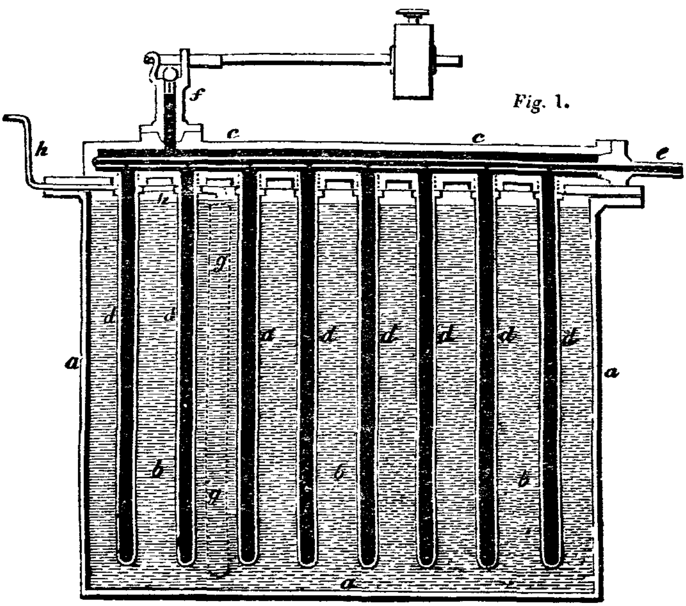


Fig. 1.

a longitudinal section of one of the vessels, and *Fig.* 2 a transverse section of both; they are made of cast iron, in the form represented at *a a a*, *b b* indicating the metallic mixture. Supported upon the cover of the metal vessel, is a strong top *c c* of the generator, containing a cylindrical chamber of 2 inches in diameter; *d d d*, are the wrought-iron generating tubes, suspended in the metallic mixture; they are of 1⅛ inch bore, and are screwed into the top

c c, so that they may be taken out whenever they require cleaning; *e* is the injection pipe, through which the water is conducted into the generating tubes, through a small perforation made over each. The double vessel, as best seen in *Fig.* 2, is suspended in the furnace, so as to expose all its four sides and ends to

Fig. 2.

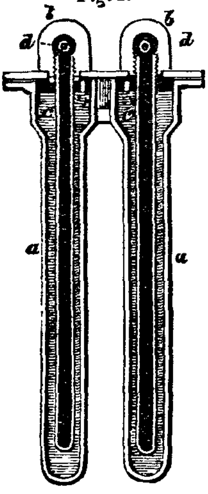
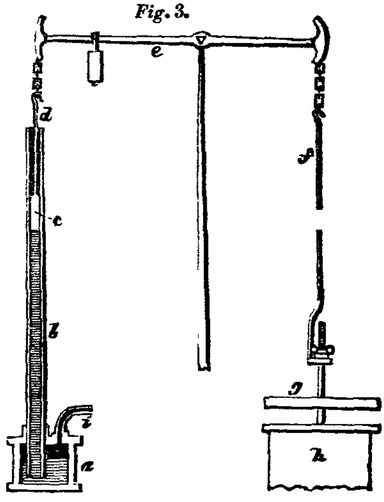


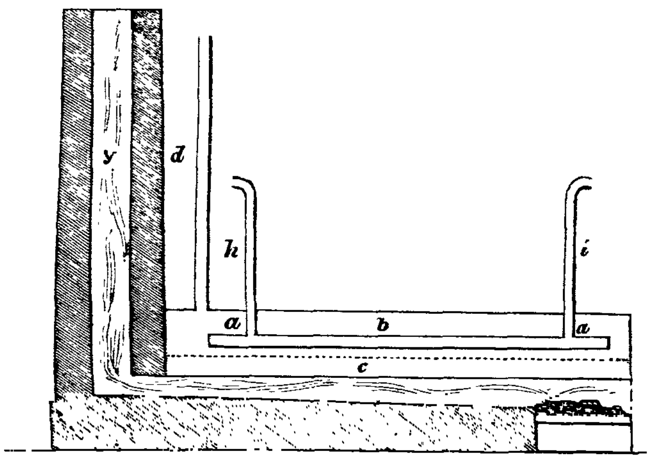
Fig. 3.



the action of the fire; so that although it is but 4 feet long, 3 feet 6 inches high, and 9 inches wide, it exposes a surface of 64 feet to the fire. The two injection tubes are connected externally, and communicate in one pipe with the forcing pump. This pump is of the usual construction, furnished with a lever and weight, which are raised by the engine. If the production of steam in the generators be too great for the wants of the engine, the pressure in the steam chamber will act against the injection, and the weight will be insufficient to force down the piston of the pump, which will thus remain inactive, until the pressure is diminished by the ceasing of production and the expenditure of the engine. To prevent the metallic fusion from being overheated, in cases where a smaller supply of steam is required, or where a suspension of steam generation takes place, by the stoppage of the engine or otherwise, the inventor has arranged a heat regulator, which governs the intensity of the fire. The apparatus indicates the temperature of the fused metal, upon which solely its action depends, and the generation of steam in the generators has no influence whatever upon it, the regulator continuing to act when the generation of steam has ceased, on which account it appears to be essentially different from any heat regulator previously used. Its application to this apparatus is indispensable, to prevent such a heating of the generating tubes as might occasion a decomposition of the water injected therein. It consists of two pipes filled with atmospheric air, one of each being inserted into each vessel, (*Fig.* 1, *g*) and surrounded by the metallic medium. To both pipes, very narrow tubes are fixed, shown at *h*, *Fig.* 1, and *i*, *Fig.* 3; these are joined externally into one tube, which opens inside the mercurial cistern *a*, *Fig.* 3. Within the mercury therein contained is immersed a vertical tube *b*, with a float *c* swimming on the top of the mercury. This float is connected, by means of the rod *d*, with the rod *e*, and acts by the rod *f*, upon the damper *g*, which regulates the draught of the fire in the ash-hole. When the air in the pipes, *Fig.* 1, *g g*, becomes heated by the fusion, it expands progressively as this becomes hotter, presses on the mercury in *a*, *Fig.* 3, and causes it to ascend in the tube *b*. By the rising of the mercury, the float *c* is made to ascend likewise, and acts by the rod *d* on the lever *e*, and thereby on the damper *g*, so that should the temperature of

the fusion be greater than is required, it gradually closes the air-hole *h*, by which the supply of air to the fire is prevented, and the heat consequently diminished. Although the intelligent inventor of this apparatus was, as we are informed, unsuccessful in the introduction of it, yet it has strong claims upon the attention of engineers for the originality and ingenuity of many of its arrangements. The employment of a fluid metal, possessing a high conducting power, for the heating medium, instead of an inflammable substance like oil, possessing but feeble conducting power, promised much better results, while it rendered the use of the apparatus perfectly safe.

Mr. Porter, a scientific gentleman, who was connected with Dr. Alban in the last described project, subsequently invented, in conjunction with Mr. Beale, an engineer, the third plan we have alluded to. In this apparatus, the arrangement is such as to render it impossible to impart a higher degree of heat to the generator than the boiling point of the fluid employed as the medium, as the vapour from the latter is allowed to escape as it is formed. The annexed figure affords a longitudinal section of the apparatus; *a a* is the vapour chest, formed of thin plate



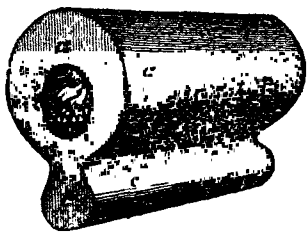
iron; *b* the generator, which this drawing may be considered as representing by an edge view of a system or coil of wrought iron tubes; the dotted line *c* marks the height of the fluid medium; *d* the "breathing-pipe," which in the event of injudicious firing, serves as an outlet and condenser, for such portion of the vapour as may not otherwise be condensed by the lower temperature of the boiler; *e* an ordinary furnace and flue; *f*, the ash-pit; *g* the chimney; *h* the supply pipe to the generator, through which water is injected by means of a forcing pump, worked by the engine; *i* is the steam pipe communicating with the engine. The water injected through the supply pipe *h* being exposed, during its progress through the generator, to the heat of the vapour furnished by the boiling fluid underneath, is thereby converted into steam, with a temperature and elastic force answering to the temperature of the vapour, which, losing a portion of its heat, resumes the liquid form, and falls to the bottom of the chest *a*, while the partial vacuum formed by its condensation causes a fresh portion of vapour to supply the void, and thus keep up a constant action. It is manifest that the temperature of the steam must be uniform, and that no greater degree can be communicated than the boiling point of the fluid medium chosen, and all injury to the machinery is therefore avoided, while, from the same cause, all those sudden accessions of elastic force, which have frequently proved so disastrous, are rendered impossible. This mode of heating has, we are informed, been very successfully employed in the preparation of vegetable extracts, and in other chemical operations where regulated degrees of heat are essential. As respects

its application to the generation of steam for engines, we are not aware of its having been so used by any other persons besides the patentees. Objections have probably been raised to the combustible media employed in the vapour chest, and the expense attending the supplying the loss of it occasioned by evaporation. These media were chiefly the spirit of turpentine, naphtha, naphthaline, and other products of coal tar, forming a variety of mixtures, whose boiling points vary from 200° to 700° Fahrenheit.

In the former part of this article, we have had occasion to notice the inconvenience arising from the deposit in boilers, and to mention some of the modes adopted for cleansing them. Occasionally these deposits are several inches in thickness, and as hard as the artificial stone pottery, caused by the baking they receive while in contact with the metal of the boiler, which receives the direct action of the fire. To remove these incrustations is a work of considerable labour; it being a general practice for workmen to get inside the boilers, and break up the stony matter, by means of heavy hammers and cold chisels. These deposits are also the cause of other serious inconveniences; they form a non-conducting shield between the fire and the water, rendering the boiler liable to become red-hot, by which its destruction or premature wearing out is effected, and a considerable waste of fuel is made. To obviate these injurious tendencies, a variety of plans have been proposed. Some engineers throw into the boiler a quantity of some fibrous and mucilaginous vegetable matter, such as bran or husks, to which the earthy matter in the water adheres, and is thereby prevented from becoming concrete and hard, and consequently more easy to be removed.

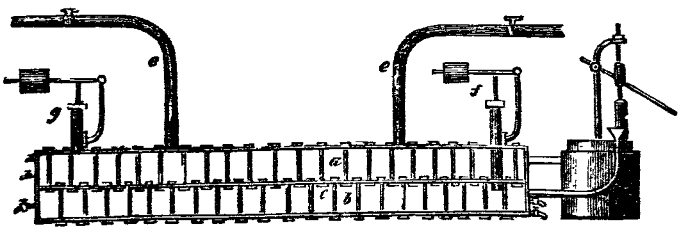
In the year 1828, Mr. Anthony Scott, of the Southwark Pottery, Durham, took a patent for a very obvious and effective contrivance to abate this evil. His plan is to place a number of slabs or trays of metal stone or wood near to the bottom of the boiler, which it is said so reduces the agitation of the water during the ebullition, that nearly the whole of the sediment descends by its own gravity, and deposits itself in the trays, instead of on the bottom of the boiler. The transmission of the heat is not intercepted by this arrangement, while the trays are removable at pleasure, for clearing them of the sediment deposited upon them.

More recently, (in 1830,) Mr. William Taylor, of Wednesbury, took out a patent, having for one of its leading objects the prevention of the incrustation and removal of the sediment, without stopping the operation of the boiler. It consists of a sediment trough or vessel, extending the whole length of the boiler, immediately under it, with a valve opening at one end, through which a portion of water is occasionally permitted to escape with great velocity, arising from the pressure of the steam, that it may carry with it whatever deposit may have settled in the bottom. This arrangement is represented in the annexed sketch; *a a* is a cylindrical boiler, having a fire place *b*, and a flue within it; *c* is the deposit vessel below the fire. When this invention is applied to boilers which have the fire under, instead of inside them, the patentee applies a deposit trough on each side, and these must be shielded from the action of the fire. The claim to invention under this patent is limited to the particular modifications described; as deposit vessels have, before the date of Mr. Taylor's patent, been applied to boilers; and they are undoubtedly appendages of great utility. On account of the great deposition of salts, and other earthy matters, on the bottom and sides of boilers employed in steam boats at sea, it becomes expedient, in long voyages, to stop the progress of the vessel, in order to discharge the contents of the boilers, and fill them anew; for if the heat be continued after a considerable deposition has taken place, the steam can only be raised by a greatly increased expenditure of fuel, and the augmentation of the heat materially injures the tenacity of the metal of which the boilers are



composed. To obviate so great an inconvenience, Messrs. Maudslay and Field have proposed an arrangement of apparatus, by which the water is continually being changed, and for which they took out letters patent in 1824. These gentlemen state that from 20 to 30 per cent. of the quantity of water evaporated, being taken from the concentrated brine, will keep the water within a degree of saltness from which no practical evils will result, however long the boiling be continued; the quantity thus abstracted from the boiler being of course replaced by a like quantity of sea-water in its natural state. The abstraction of the brine is made by means of a small pump, with a loaded discharge valve, worked by the engine, and so proportioned as to draw from the lowest part of the boiler the quantity determined on, which may be regulated by a meter, shewing the quantity of water driven off in the form of steam. The operation of the pump is, however, not to commence until the brine has attained a considerable degree of concentration; it should for instance contain five times as much salt as common sea water does; after this, every stroke may be made by means of the pump, to take as much salt out of the boiler as is deposited in the boiler by the separation of the steam used in that stroke. By these means, the water in the boiler can never exceed a certain predetermined degree of saturation; and whether the engine be working quickly or slowly, the quantity withdrawn may always be made to bear the same proportion to the quantity left in, thus avoiding one of the greatest evils to which steam vessels in making long voyages have been subjected. To economise the heat and consequent expenditure of fuel, Messrs. Maudslay and Field further propose that the hot brine extracted by the pump be discharged into a vessel containing a series of metal pipes of small calibre, similar to a refrigeratory. Through these pipes, which lie immersed in hot brine, the supply water is to be made to pass in order to abstract the heat in its progress, and deliver the sea-water into the boiler in a heated state.

In the year 1824, Mr. Smith introduced, in some of the salt works of Lancashire, a mode of evaporating brine, by the application of high-pressure steam under the salt pans; and as the surfaces of these vessels are very extensive, they are incapable of sustaining much pressure. Mr. Smith, therefore, tied the bottom of the boiler to the bottom of the pan (which also formed the top of the boiler), by means of screw bolts and nuts, in the manner shewn at *b* in the subjoined sectional figure. Finding this arrangement productive of a safe and



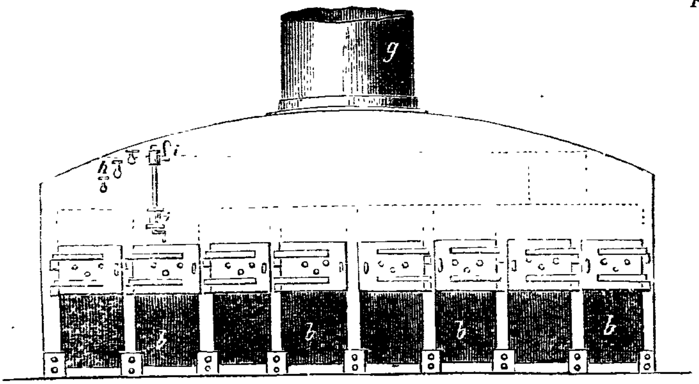
efficient generator of high pressure steam, he subsequently took out a patent for a modification of it, to be applied to steam engines. This modification chiefly consisted in the addition of the upper vessel *a*. The plan of these vessels is supposed to be a parallelogram, and the screw bolts about 9 inches apart in each tier, over their whole surfaces. The water is supplied by a force pump, as represented, and a number of guage cocks are fixed at different elevations, as shewn in the drawing, to ascertain the height of the water, and the state of the steam in each vessel. *e e* are steam pipes; *f* is a safety valve to the lower chamber *b*, and *g* another to the upper chamber *a*. The patentee states, that "about two inches of water are put into the lower vessel, and the other being half filled, the fire is lighted, which quickly raises the water in the lower vessel to ebullition, the steam of which acts upon the lower surface of the upper boiler, giving out its heat to the water contained therein, and is thereby itself condensed;

and being thus alternately vapourized and condensed, the upper vessel is converted into a steam chamber of uniform temperature." Although this boiler is calculated to generate steam with rapidity, owing to the extensive surface of metal exposed to the direct action of the fire; and notwithstanding it must be deemed safer than most others of equal capacity and effect, by reason of the numerous tie bolts; it must, we think, be expensive in construction, and very difficult to preserve free from leakages.

In the generality of boilers the flue first takes a horizontal direction, more or less extended, and afterwards ascends the chimney; sometimes it is also made to descend; and in almost every way that ingenuity could devise, the flues have been made to encompass the water, for the purpose of transmitting their heat thereto. Mr. Joseph Gibbs, of Crayford, in Kent, has, however, invented a boiler, (patented in 1830,) which possesses some claims to originality of arrangement; and as it probably confers some advantages, we shall here notice it. The form of the upper portion of this boiler is circular, with a descending cylindrical branch of considerable magnitude and length, the latter being quite full of water, and the upper filled to about four-fifths its depth, the remaining one-fifth being reserved for steam room. In the middle of the upper vessel is the fire-place, the air for combustion being supplied by a vertical pipe, passing upwards through the descending cylindrical branch of the boiler. The products of combustion first act upon the water in the upper vessel, whence the flue descends in a curvilinear direction around the vertical air pipe in the midst of the water contained in the descending branch of the boiler, to the bottom thereof, and thence into the chimney. For the ready passage of the smoke, a temporary flue, which proceeds in a direct line to the chimney, is opened whilst lighting the fire, after which it is stopped by a damper or valve, which causes the current of heated matters to take the descending course described. By this arrangement, Mr. Gibbs extracts the gaseous products of the fuel, till they are reduced to nearly the temperature of cold water, the supply water being introduced where the flue terminates. In the specification of this patent, Mr. Gibbs has also represented a long cylindrical boiler, placed horizontally, with three descending branches, and another with a flue in a zigzag direction, through the descending part of the boiler, which, although it has the advantage over the others of being of more easy manufacture, is not so favourable to the descent of the current. The partial action, owing to the unequal distribution of heat upon the different parts of a boiler, it was long since observed had a tendency to produce circulating currents of water throughout the vessel. This motion of the fluid has of late years been deemed of so much importance in the economical generation of steam, as to have induced several engineers to obtain patent privileges for their schemes: amongst these, Mr. Jacob Perkins is most conspicuous, for having taken out two patents for the same object, one in 1831, and the other in 1832. But as nature is inclined to perform the circulatory process pretty well without the assistance of art, we shall dismiss the subject with a brief notice of the above-mentioned gentleman's plans. In the first of these, Mr. Perkins placed a thin metallic lining inside of the boiler, at a small distance from the bottom and sides, but leaving an opening in the lining at the bottom, where the heat of the fire is the strongest. Here, therefore, the water will acquire the greatest levity, and consequently ascend, while the water next to it, which is that between the lining and sides of the boiler, will occupy the bottom of the rising column, and thus a constant circulation will be kept up through the whole of the fluid in the vessel. In Mr. Perkins's second patent, which is stated to be for improvement on his former one, the aforesaid linings are to be augmented so as to cover a more extended surface, and form nearly a complete internal vessel at a few inches distance from the external one. It would require a large volume to describe the multiplicity of forms that have been introduced in the construction of boilers and their appendages, with the view of economising the production of steam. Those which we have already given, however, afford a general outline of the whole, with the exception of such as are employed in steam navigation. In these, it is an essential condition that the fire-place and flues should be entirely surrounded with water, so as to

prevent any contact of those parts with the wood-work of the vessel. We shall give two examples of boilers of this description.

Fig. 1.



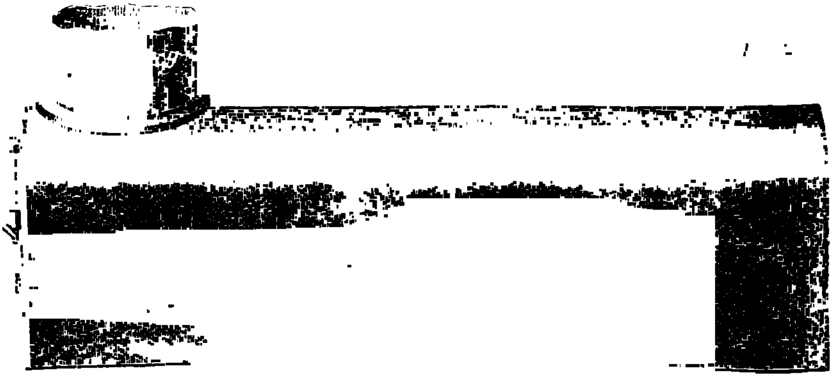
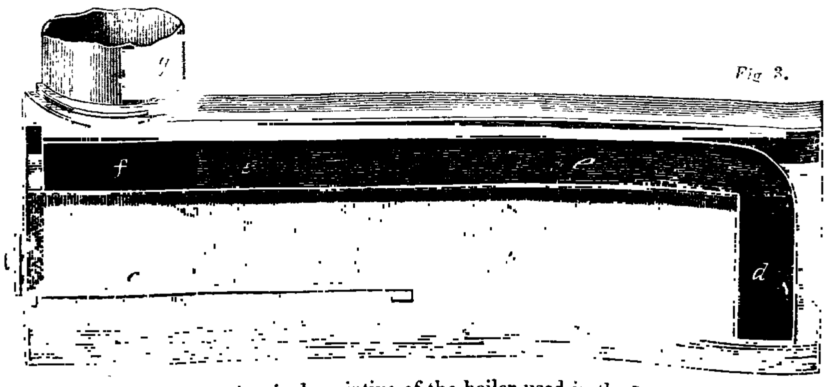


Fig. 3.



The above engraving is descriptive of the boiler used in the United Kingdom steam packet, of 1,000 tons burthen, measuring in her keel 148 feet, and breadth of beam 14 feet, and propelled by two engines of 100 horses each, manufactured by Mr. Napier, of Glasgow. The boiler is of wrought iron plates,

25 feet 6 inches long, 19 feet broad, and 8 feet 6 inches high. There are eight rectangular tubes *b b* running lengthways of the boiler; in each of these is a fire at one end on the bars *c c*, shown in section. At the farther end of the tubes is a transverse one *d*, extending the whole breadth of the boiler, which communicates with every one of the tubes containing the fire; at each end of *d* on the top, a return tube *e e* carries off the smoke and fire into another transverse tube *f*, out of the centre of which the chimney *g* rises. The cocks *h h h* are for ascertaining the height of the water in the boiler; but there is added a simple contrivance, by which the necessity of employing the cocks *h* is avoided. There are two cocks *i i* which are placed the one considerably above, and the other as much below, the assumed level of the water; these cocks communicate with a vertical tube of glass *j* of sufficient strength to withstand the force of the steam. On the cocks *i i* being opened, water enters into the lower one, and steam into the upper one, and the pressure being the same in the boiler, the water stands at the same level in the glass tube, which indicates the height of the water in the boiler.

In the subjoined engraving, which represents a patented arrangement by Mr. Steenstrup, a Swedish gentleman, in this country, the boiler is divided into

Fig. 1.

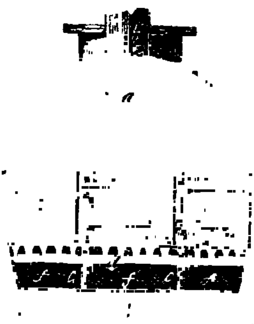


Fig. 2.

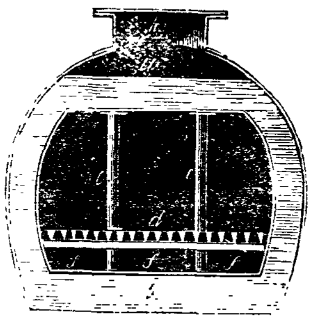
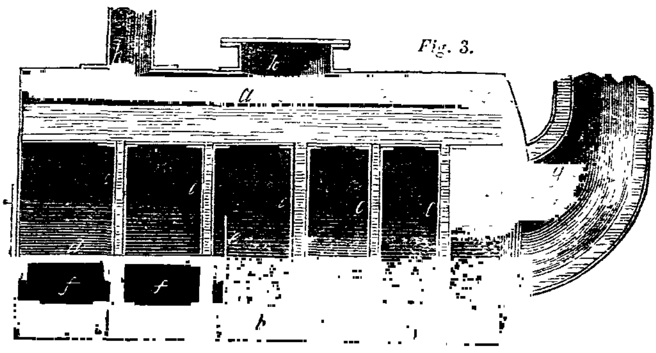
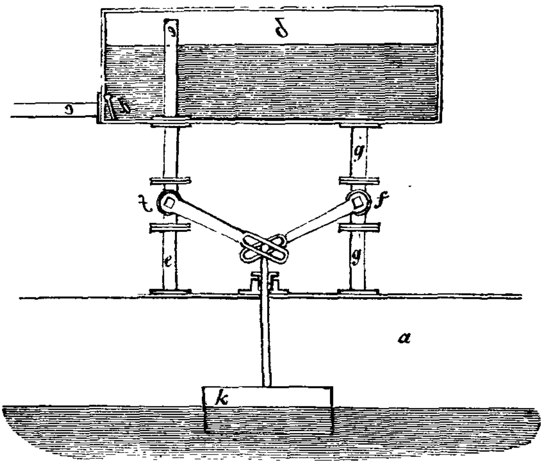


Fig. 3.



an upper and lower chamber, in connexion with the side chambers, and by means of vertical tubes. *Fig.* 1 is an end elevation of the boiler; *Fig.* 2 a transverse section; and *Fig.* 3 a longitudinal section, the same letters designating similar parts in each. *a* is the upper division, or steam chamber; *b* the lower chamber, connected with the upper by the side vessels, and by the vertical tubes *c c*, as shown in the section; at *d* is the fire bars, on which the fuel is deposited; *e* the fire bridge; *f* the ash pit; *g* part of the chimney, likewise surrounded with water at the lower end, which is in contact with the vessel; *h* is the steam

pipe, and *k* the man-hole. It will be observed that the vertical tubes *c c* besides forming a support to the weight of water in the upper chamber, and opening a free communication with it, receive, from their position in the fire-place, the strongest heat, and consequently give off steam quicker than the other parts of the boiler, in particular those which pass through the fire bars, producing thereby those ascending and descending currents, which are deemed so advantageous in the generation of steam: also, from the great capacity of the fire chamber, that fuel of any kind, however bulky, may be easily employed, by merely shifting the fire bridge accordingly. In the description of the common waggon-shaped boiler, in the early part of this article, the manner usually adopted of feeding boilers with water was explained. The necessity of a due supply of the fluid is so great, as to have induced numerous inventors to devise plans for insuring its accomplishment. Several of the most approved arrangements for this purpose are detailed in Galloway and Hebert's History of the Steam Engine; and we shall close the present article by the description of another of great simplicity and effectiveness, which was patented by Mr. W. Taylor of Wednesbury, since the

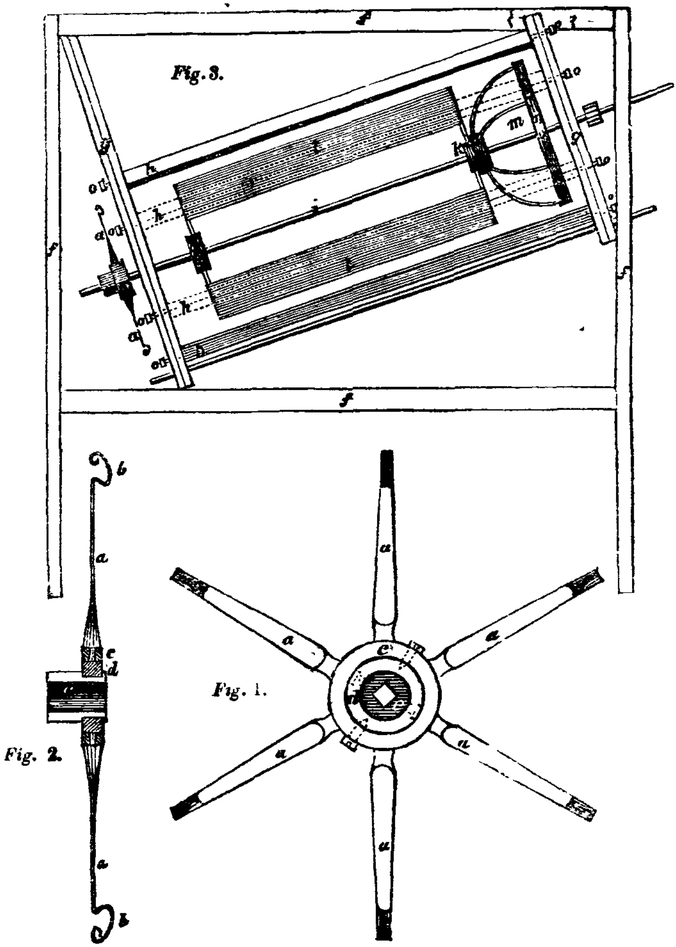


publication of the before-mentioned work. In the above figure, *a* shows a portion of the boiler; *b* a water reservoir or feeding vessel, made steam tight; *c* a pipe through which *b* is supplied with water, having a valve *d* opening inwards. *e* is a steam pipe, extending from the boiler to nearly the top of the close vessel *b*, and *c* is a water pipe extending from the bottom of the close vessel to the interior of the boiler. In both these pipes are stop cocks *e* and *f*, with levers extending to *g*, by which they are opened and closed. In these levers are two longitudinal slits, for the reception of a pin fixed in a rod extending from the float *h*, through a stuffing box in the top of the boiler. Now when the water in the boiler evaporates till its surface descends, and permits the weight of the float to bring down the levers to the position represented, the cocks will be opened, and the steam will rise through the pipe *e*, by which the pressure will be equalized in the boiler *a* and the supply vessel *b*, and water will descend through *f* till its surface in the boiler rises sufficiently high to raise the float and shut the valves; and then the condensation of steam in *b* will cause a partial vacuum, permitting a fresh dose of water to pass through *c* into the feed vessel.

BOLOGNIAN STONE. This stone is the ponderous spar, or native sulphate of barytes, the phosphoric property of which was first discovered by an Italian shoemaker. If it be first heated to ignition, then finely powdered, and made into a paste with mucilage, and this paste divided into pieces a quarter of an inch thick, and dried in a moderate heat, be exposed to the heat of a wind furnace, by placing them loose in the midst of the charcoal, a pyrophorus

will be obtained, which, after a few minutes' exposure to the sun's rays, will give light enough in the dark to render the figures on the dial-plate of a watch visible.

BOLTING MACHINE. A part of the machinery of a flour mill, by which the flour is separated from the meal, which operation is termed *dressing* the flour. It usually consists of an hexagonal reel, over which is drawn a sack, called the bolting cloth, of considerably larger diameter than the reel, and composed of a peculiar species of duck made for the purpose. The reel is placed in an inclined position, and made to revolve rapidly within six bars of wood, called beaters, fixed to a case or box, within which the reel revolves. The



reel being turned with great velocity, the centrifugal force would throw out the bolting cloth to its utmost extent were it not intercepted by the beaters; the repeated blows from these first force the flour through the interstices of the cloth, and subsequently, at the tail end of the reel, the offal consisting of bran, pollard, and sharps. The above engraving represents Ayton's improved Flour Bolting Mills, constructed upon the principle just described, but provided with the means of more easily and effectually regulating the tension and elas-

ticity of the bolting cloth, so as to produce in it a uniform and powerful vibration, which is effected by secured loops at one end of the cloth to six elastic steel arms or springs, instead of the stiff arms of the common construction.

Fig. 1 is a plan or front view of the steel arms *a a*, and *Fig.* 2 a side view of the same in section. These arms are rivetted to a ring of metal *c*, and at their outer extremities are formed into broad flat hooks to receive the loops of the bolting cloth, for which purpose they are nicely rounded and smoothed. The ring *c* is secured by two conical pointed screws to another ring *d*, placed within *c*, sufficient space being left between the two rings to allow a small degree of play. The ring *d* is in like manner secured to the central socket *e* by means of two other conical pointed screws, with a similar allowance for play; the two rings *c* and *d* forming a kind of universal joint. The socket *e* is put over the square part of the spindle of the reel, and fixed at any part of its length by means of a tightening screw. *Fig.* 3 represents the improved bolting machine, with the front pannels of the case in which it is inclosed in order; the beaters *h h h h* are fixed, the two which are in front of the machine being shown in dotted lines; *i* is the revolving axis or spindle, to which is fixed a light hemispherical frame *m*, over which the bolting cloth is drawn, and made fast to the circular ring or curb *n*, by means of a string running in a band of leather sewed to the head of the cloth to strengthen it; the loops to the "tail leather" at the other end of the machine are fixed to the spring arms *a a*, already described and shewn in their place upon the axis *i*, by which means the most perfect and equal tension of the bolting cloth is obtained, and the beaters being adjusted to a proper distance, the operation of bolting is very effectually performed. Another improvement, although not claimed in the patent, is the substitution of four cloth fanners for the wooden rails, which compose the reel in the ordinary machine. The fanners are constructed as follows: upon the spindle *i* are fixed two "maces" or bosses *k k*, from each of which radiate four arms; from each of the arms on the mace, a piece of duck, about six inches broad, is stretched to the arms of the other mace as shewn at *l l*. When a rapid motion is given to the reels, the pieces of duck *l l* set the air in brisk motion, by which much of the flour is forced through the bolting cloth, the tension and tremulous motion of which, by the elasticity of the springs, tend to prevent the clogging up the interstices of the cloth, and the operation of bolting proceeds with great regularity and expedition. Accompanying the description of the machine in the patentee's circular, are several certificates from respectable millers of its superior efficacy, which state that nearly double the quantity of meal is bolted in a given time. There is another description of dressing machine, in which a cylinder composed of wire gauze of various degrees of fineness is employed to sift the meal instead of a bolting cloth.

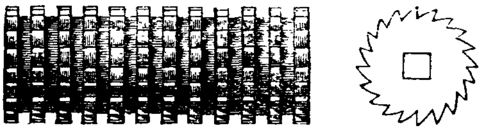
BOMBASINE. A well known stuff, produced by various mixtures of cotton and silk.

BONE ASH. The residue of burnt bones. The process is conducted in the open air, in large heaps, and the earthy salt which remains forms on an average about half the weight of the fresh bone. It is composed chiefly of phosphate of lime, and is used by the assayers as the material for cupels, and for other purposes.

BONES. The hard insensible substance of which the frame or skeleton of animal bodies is formed. Although the proportion of the ingredients vary in the bones of different animals, as also in different parts of the same animal, the general constituents of bones are as follows: gelatin or jelly, soluble in hot but not in cold water; fat, separable by boiling, when it rises to the top of the water, and becomes concrete in cooling; phosphate of lime in large quantity; a little sulphate and carbonate of lime; and a cartilaginous substance retaining the form of the bone after every thing else has been extracted, by boiling and by acids. The uses of bones in the arts are very numerous. Both in their natural state and dyed, they are made into knife handles and various articles of turnery ware. They are extensively used in the manufacture of ammonia, the refuse forming bone black; or calcined to whiteness in the open air, they form bone ash, which see. They are also employed in the preparation of milky

glasses and porcelains, for the rectification of volatile oils, and in the preparation of glue; and recently in France, large quantities of gelatin have been extracted from bones, which has been subsequently made into soups for hospitals, soldiers, and restaurateurs. The process is as follows: the bones are first broken into small pieces, and then thrown into a kettle of boiling water, and boiled for a quarter of an hour. When this has become cold, a quantity of fat, amounting in some instances to nearly a fourth of the weight of the bones, is found at the surface of the liquor, and is applicable to many useful purposes. After this, the bones are ground, and boiled in eight or ten times their weight of water, until about one half is wasted, when a very nutritious jelly is obtained. M. Darcet recommends, instead of grinding the bones, which is a work of great labour, to treat them with dilute muriatic acid, which dissolves the salts of lime, leaving the gelatin untouched, and retaining the form of the bones; this is afterwards to be repeatedly washed in clear cold water to free it from all taste of the acid, and then if not required for immediate use, to be thoroughly dried by long exposure to a gentle heat, after which it is little affected by the atmosphere, and will keep for a great length of time. It should be observed, that the bones should not be boiled in copper vessels, as gelatin quickly attacks that metal. Bones are likewise extensively used in agriculture as a manure, when reduced to a coarse powder; and large quantities are collected for this purpose from various parts of the kingdom, as well as from abroad, and sent to Yorkshire, where most of the bone mills are established, to be ground. The annexed, *Fig.* 1, represents a side elevation

Fig. 2.



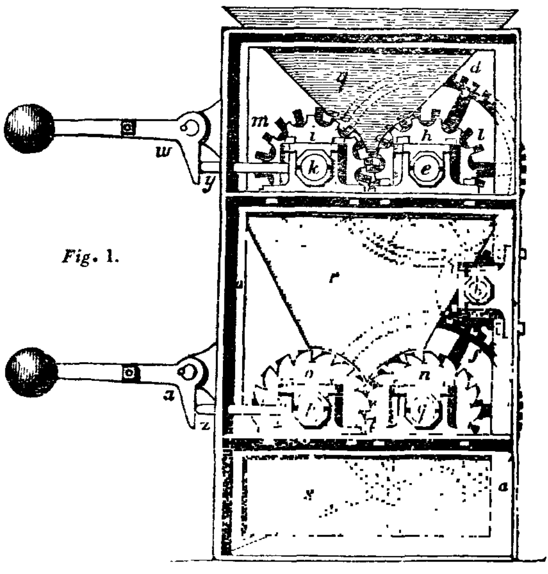


Fig. 1.

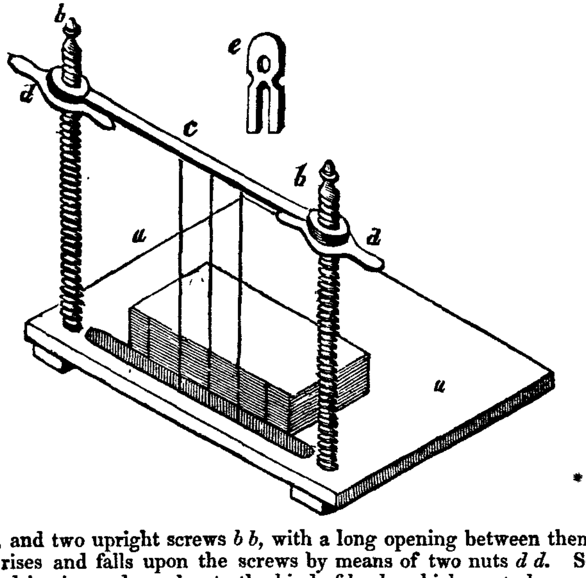
of a bone mill of an approved construction. *a a* is one of the side frames, *b* the driving shaft carrying a pinion *c*, which turns the wheels *d* to the axis *e*, and the wheel *f* upon the axis *g*; *h i* are a pair of fluted rollers fixed to their respective shafts *e* and *k*, and turning in contrary directions by the action of the two wheels *l* and *m*, also affixed to the same shafts; *n* and *o* are another

pair of rollers affixed to the shafts *q* and *p* respectively, and likewise turned in contrary directions by a pair of wheels upon the same axes. These rollers are composed of a series of wrought iron discs, with teeth resembling those of a ratchet-wheel, and fixed up the shaft, with a plain disc of smaller diameter interposed between each pair of the toothed disc, as shewn in *Fig.* 2, and so arranged that the toothed discs on one shaft shall face the plain discs on the other. The most valuable part of the bones is first removed by a circular saw, and set apart for the uses of turners and others; the joints and refuse are then put into the hopper *q*, and descending upon the rollers *h i*, are crushed, and fall into the hopper *r*, whence they pass between the rollers *l m*, where they are reduced to a coarse powder, which is conducted by the shute *s* (in dotted lines) to the receiver. To prevent the teeth of the rollers being broken by any excessive resistance, the plummer blocks, which support the shafts *k* and *p*, are not *fixed* to the side frame, but are retained in their places by pins passing through chase mortises in the frames, allowing the blocks to slide along the frame, and the rollers are kept in contact by means of weighted levers *w a*, pressing upon short studs *y z*, attached to the plummer blocks, which carry the shafts *k p*.

BOOKBINDING is the art of securing together a number of separate leaves into one book, and is of very great antiquity, the invention being generally attributed to one of the kings of Pergamus, to whom we are also said to be indebted for the invention of parchment. Bookbinding, properly so called, includes the binding of all printed books; while vellum-binding is the term applied to the binding of every description of account books. The two branches are quite distinct, and seldom, if ever, successfully practised by the same individual; we shall therefore describe each branch separately, beginning with bookbinding. Although the limits of this work preclude the possibility of entering minutely into all the practical details of the subject, yet it is hoped that the following account will be found to contain a clear and connected view of the nature of each process, and of the tools employed, with a brief notice of some of the more striking attempts at improvement.

In binding printed books, they are generally received by the binder in sheets, which are folded into quartos, octavos, duodecimos, &c., as the case may be. This process is assisted by certain catch-marks or signatures, printed at the bottom of each sheet, by attending to which, and keeping the folio of one page on the folio of another, and at the same time preserving the necessary correspondence between the foot of each page, the work will be properly folded, and an uniformity of margin preserved throughout the work. The book having been folded and pressed, is next beaten on a large smooth stone, with a cast iron bell-shaped hammer, weighing from twelve to fourteen pounds. This beating requires great care and skilfulness on the part of the workman, and various attempts have been made, at different periods, to supersede the process, by the use of hydraulic and other powerful presses; these, however, have proved unfit for the purpose, generally creasing and disfiguring the work. Mr. Burn, of Hatton Garden, has, however, succeeded in rendering books extremely compact and solid, by passing the sheets, when folded, between a pair of powerful rollers; and this method will eventually supersede the old laborious and imperfect one of hammer-beating. The apparatus of Mr. Burn consists of two iron cylinders, about 12 inches in diameter, adjustable in the usual manner by screws, and worked by manual labour applied to one or two cranked handles. A boy sits in front of the press, who gathers the sheets into packets by placing two or more upon a piece of tin plate of the same size, and covering them with another piece, and thus proceeding, by alternating tin plates and bundles of sheets, till a sufficient quantity have been put together, which will depend greatly on the thickness and hardness of the paper, &c. The packet so formed is then passed between the rollers, and is received by the man who turns the winch, and who has time to lay the sheets on one side, and hand over the tin plates, by the time that the boy has prepared a second packet. The time occupied in this process is about one-twentieth of that requisite for beating. It is not merely a saving of time, however, that is gained by using the rolling-

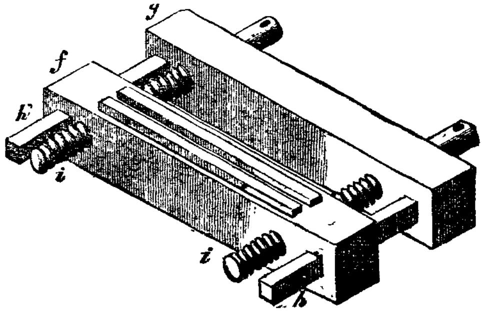
press, for the paper is rendered much smoother, and the compression of the book is one-sixth greater than could have been obtained by beating. The Society of Arts presented Mr. Burn with their silver Vulcan medal for his invention, which is now in very general and extensive use. Newly-printed works will not admit of beating or rolling, and books which are only to be boarded, do not require more than a good pressing. After beating or rolling, the book is collated, and the plates (if any) put in their respective places. It is then put in the standing press, and after remaining there a short time, is taken out, and the waste leaves added at the beginning and end. The book is then taken up between the extended fingers of each hand, and the back and head knocked up nice and square; one side of the book is then laid upon a pressing board as large as the book itself, beyond which the back must project about half an inch; a second pressing-board, corresponding in size and position with the former, is placed upon the upper side, and the board being firmly grasped with the left hand, the book is lowered into the cutting-press, which is screwed up tight, and a certain number of grooves, according to the size of the book, are cut in the back with a tenon saw, for the reception of the cords on which the book is to be sewed. After sawing, the sections are parted by passing a folding stick up and down between them. The book is then taken to the sewing-press, of which the accompanying is a representation. It consists of a stout flat



board *a a*, and two upright screws *b b*, with a long opening between them. A top rail *c* rises and falls upon the screws by means of two nuts *d d*. Several cords, suited in size and number to the kind of books which are to be sewn, are attached to the rail *c*, and set to correspond with the sawed grooves in the back of the book; the cords being carried down through the aperture in the bed of the press, are fastened underneath by means of brass keys, of which *e* is a representation. The number and distances of the bands are quite arbitrary, and are disposed according to the fancy of the workman; it may, however, in general, be regulated as follows: 32mos. three bands; 18mos., 12mos., 8vos., and two-leaf 4tos. four bands; royal 8vos. and whole-sheet 4tos. five bands; and folios from five to seven bands. In sawing the back two extra grooves are made, one at each end of the book, for the catch or kettle-stitch. The book being placed with the back towards the sewer, and the title uppermost, the fly-leaf or end paper is first laid upon the press and sewed to the cords, by passing the needle in the first right-hand groove or catch-stitch mark, with the right hand; the left hand being kept in the middle of the section, receives the needle

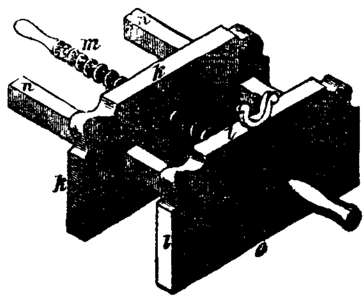
and draws it through, leaving two or three inches of the thread undrawn. The needle is then returned out on the head side of the band, received by the right hand, and passed through on the other side of the band, by which the thread is conducted round each band in succession. The needle being carried along the inside of the section, and led round each band in this manner, is at last brought out of the last groove or left hand catch-stitch mark. The first section of the book is then taken and sewed to the bands in the same way; when the needle comes out at the catch-stitch mark, over the end of the thread left out of the fly-leaf in the first sewing, the thread is tied to it in a knot. The remaining sections are then sewn, the thread being fastened through the catch-stitch of each preceding section. Care must be taken not to draw the thread of the catch-stitches too tight, but to keep the back equally swelled. A number of books may be sewed one on another, till the press is three parts full, care being taken to finish off the sewing of each book, and not to catch-stitch them together. The proper number of books being sewed, the strings are cut from the rail, and unfastened at the bottom; the books are then separated and the bands cut apart, leaving about two inches on each side of the book. After sewing, the back of the book is glued; and when that is dry, the ends of the bands are opened and scraped. If the book is to be lined, which is customary with all half-extra and other superior work, it is now done, either with fine coloured or marble paper. If with marble paper, the sheet is folded with the plain side outwards, one half of it being pasted; it is laid between the fly-leaves, into the fold of which it is closely worked; the other half is then pasted, and the next fly-leaf rubbed down upon it, any superfluous edges being cut off with the shears. This done, the back is next to be rounded, which is effected by laying the book on the press cheek, with the fore-edge towards the workman, who presses the fingers of his left hand upon the book, and at the same time draws it towards him, gently tapping the back up and down with a hammer, alternately changing the sides until the book is uniformly and effectually rounded. The back is then squeezed in the cutting press for a few minutes, which sets it, and the book is then ready for *backing*. This consists in forming a projection of the back on each side of the book, sufficient to cover the boards, and is done by placing cutting boards on each side of the book, within about a quarter of an inch of the back, or according to the size of the book, care being taken that the boards are parallel with the back, and at equal distances from it. The boards being tightly grasped by the left hand, are lowered into the cutting-press and screwed tight; the back is then hammered gently and uniformly all over, which causes it to spread over the boards so as to form the required ledge or projection. If any roughness appears on the back, it is removed by scraping, and cleaned off with paste and paper shavings. The boards for the cover, which are brown milled boards, having been cut to the required size with shears, or ploughed in the cutting press, two holes are pricked with a bodkin for each band, one of them directly opposite the band, the other about an inch beyond it. The first, for 8vos, should be about half an inch from the edge of the board, the others about an inch, or for larger works still forwarded. The bands are then drawn through the outer side of the board, and passed through the other hole to the outside again, where the ends are spread and pasted. Each board is then opened, and laid separately on a smooth piece of iron, and the strings hammered flat. The boards, which should not be put on too tightly, having been properly adjusted, and the back examined to see that it has not been deranged, and the defects, if any, remedied with the backing hammer, the next step is cutting the fore-edge. For this purpose the boards are thrown out of the grooves or ledges, and then brought to a perfect level with the back by knocking on the cheeks of the press; a *cutting-board* (of oak or beech, and rather wedge-shaped) is then placed on the left hand side of the book, and another, called a *runner*, on the right; the whole is then placed in the cutting-press, the runner being brought even with the right cheek of the press, and when properly adjusted, the press is screwed up, and the fore-edge ploughed. After cutting the fore-edge, the book is taken out, and the back rounded as before, when a corresponding groove will be formed in the front. The head is next cut by knocking the

boards straight up with it, keeping them in the ledge produced by backing; the cutting-board and runner are then applied as before, and the head ploughed. For cutting the opposite end, the boards are slipped below the head as much again as it is intended they shall project, which should be rather less than on the fore-edge. A small piece is then taken off the inner corner of each board; and the boards being replaced, there will be found a sufficient projection for both ends.

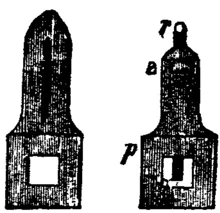


The cutting-press which has been referred to, consists of two strong wooden cheeks *f g*, connected by two slide bars *h h*, and two wooden screws *i i*. Upon the cheek *f* are two guides for the plough to work in.

The plough, which is the cutting instrument, consists of two sides, *k l*, connected by a screw *m*, and two slide bars, *n n*. A knife *o* is fastened to the under side of the cheek *l*, by a strong square bolt, which takes into a groove cut on the circumference of the screw *m*, and prevents it from moving laterally in the eheek. When the screw is turned, therefore, the two sides of the plough approach to or recede from each other.

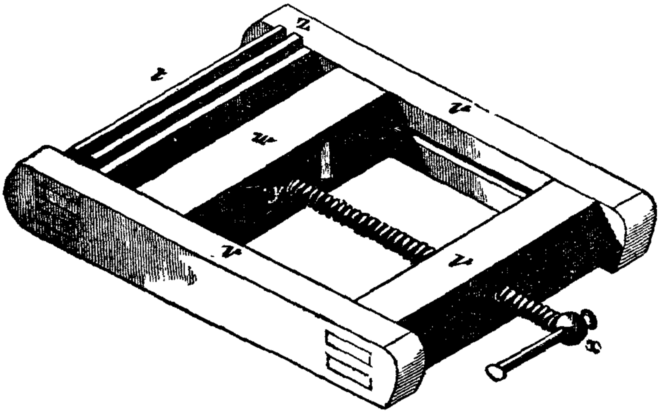


Various attempts have at different times been made to improve the cutting-press and its appurtenances. Mr. Baxter, of Lewes, proposed to obviate most of the inconveniences attending the use of the common plough-knife. His improved knife consisted of a brass or gun-metal stock *p*, having a dovetailed groove on its under surface, in which slides a steel blade or cutter *r*, which is kept in any required position by a set screw on the upper part of the stock at *s*. The great advantage of this knife is, that when once properly adjusted, the blade may be changed and ground *ad infinitum*, without deranging the adjustment of the stock.

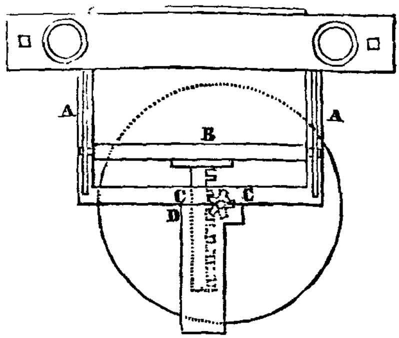


In the year 1806, the Society of Arts presented Mr. J. Hardie, of Glasgow, with a reward for an improved cutting-press for bookbinders, which is delineated in the cut at the top of page 224. *t* is the left hand cheek of the press, connected with a frame *v v v*, having two grooves on the inside, in which the cheek *w* slides backward and forward by means of the iron screw *x*, which is secured to it by a collar at *y*. *z* are the guides for the plough. The advantages claimed for this press are its simplicity, great power, and increased facility of use, as compared with other presses.

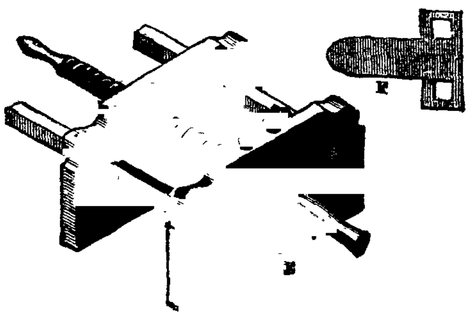
But the most striking improvement is in a cutting-press recently constructed by an ingenious mechanic named Penny, which promises to be of great practical utility; for with this press, an indifferent workman will cut the edges of books or paper with mathematical accuracy and precision, which the very best cutter with the old press could never accomplish. Penn'ys press consists of two cheeks, with screws and slide bars, as in the ordinary machine; but to the



under side of the left hand cheek, a framing A A is attached, which projects some distance under the other cheek. Within this frame, a platform B rises and falls, perfectly parallel with the upper surface of the press, by means of a rack to which the platform is attached. A pinion at C, gives motion to the rack. On the axis of the pinion, and on the left hand side of the press, there is a large wheel D which the workman turns with his hand, to give the platform the necessary elevation, fixing it in any position, by means of a small catch. As the platform moves perfectly parallel with the surface of the press, and at right angles to the frame A A,



it follows that any thing resting on the platform will be cut true throughout its whole thickness. This has been shewn to be the case, by taking off consecutively, shavings from paper the thirty-second of an inch wide, which were perfectly accurate throughout, from first to last. The surprising accuracy of this press, however, would be of little avail with ploughs and knives of the usual description. Mr. Penny has therefore so far improved the plough as to make it a fit accompaniment to his press. For this purpose, the sides, screw, and slide-bars are made with considerable care, the under surface of the sides being shod with metal, which on the right hand side is formed into an appropriate bed for the knife, as at E. The knife is of the form shewn at F; the blade is placed directly under the screw, and secured by two screw bolts, in lieu of one. The bed for the knife being metal, and the knife itself being accurately finished, no tedious adjustment is ever necessary. The knife being in the centre, stands

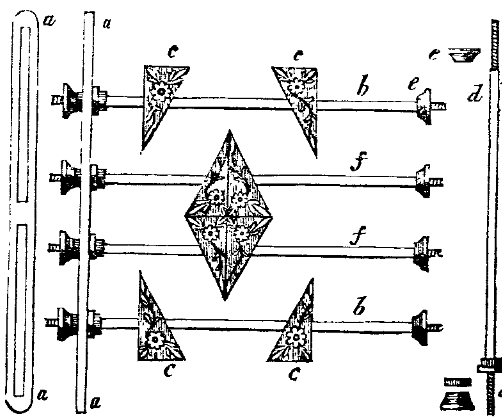


to its work well, and the plough does not twist about like the old ones. Mr. Penny received a reward from the Society of Arts, in 1832, for his improved plough. The standing-press employed by bookbinders is usually the common screw-press, worked by a long lever, to which the power of a windlass is sometimes added. Having thus briefly noticed some of the machinery which is employed by the bookbinder, we return to the book, the edges of which had just been cut; the next thing, therefore, is to ornament its edges, which is done either by colouring, sprinkling, marbling, or gilding. The first of these processes is the most simple, and is that usually adopted for the commonest work. The books being laid one on the other, or screwed in the cutting-press, the colour is applied with a sponge. The colours mostly employed for this purpose, are Spirit-blue, Brown-umber, King's-yellow, Dutch-pink, Spanish-brown, and Vermilion, mixed with size. Sprinkling is performed by dipping a stiff brush in the colour, and striking it upon the press-pin held in the left hand, by which means the colour is thrown upon the books in fine spots, and a little practice enables the workman to distribute them very equally all over the edges. Better kinds of books, however, are generally marbled on the edges, the patterns being made to correspond with the marble paper lining. Marbling is performed as follows: a trough is provided of a convenient size, about two inches deep, which is filled with clean gum-water; various coloured pigments, ground in spirits of wine, and mixed with a small quantity of ox-gall, are then thrown upon the snrface of the gum-water, and disposed in various forms, according to the pattern that is desired, with a quill and comb. The proper pattern being obtained, the book is tied between two boards, and the edges dipped into the trough, when the floating colours become transferred to the book; cold water is immediately dashed over the edges, which sets the colours, and gives them a clear appearance. If the edges are to be gilt, they are nicely cut and tied between two boards; they are then sponged over with yellow-ochre, which is scraped off, and the edges rubbed dry with paper shavings. Parchment size, or a size composed of equal parts of water and white of eggs, is laid upon the book edge, and covered with gold leaf; it is then dried gradually, and before it gets quite hard, is burnished with an agate burnisher. The edges are then protected from injury during the remainder of the process by a paper covering. Head-banding then follows. Head-bands are of two kinds, *stuck on* and *worked*. The stuck-on head-band is formed by cutting a piece of striped or coloured linen about an inch deep, and equal in length to the thickness of the book; one side is pasted, and a piece of well-twisted cord laid across one third of its width; it is then folded over, enclosing the string, and worked well up to it. The back of the book being glued, the linen is laid upon it, the cord or head-band being placed flat upon the end of the leaves. For all extra work, however, the head-bands are worked in the following manner. A strip of thick vellum, board, or string, prepared by rolling it tight in pasted paper, is taken of a dimension suited to the size of the book; stout well-twisted silk, of two or more colours, is then taken; if two colours are used, they are doubled and tied together by the ends, one of them being previously equipped with a needle. The book is then placed in the cutting-press with the back uppermost, the head towards the workman, and considerably elevated; the needle is then passed through the middle of the second section, on the left-hand side, just below the catch-stitch, and drawn out far enough to bring the knot joining the two silks close into the middle of the section; the needle is then brought up, and passed again through the same place, and the silk drawn nearly close; the round strip is placed in the loop thus formed, and the silk drawn tight with the left hand; the other silk is brought over with the right, and passed under and over the head-band, when that is held tight with the left hand; the other silk is now put over that, and also under and over the head-band; they are thus worked alternately over each other, as far as the middle section of the book, through which the needle is passed below the catch-stitch, and brought over the head-band, when the working is proceeded with as before, as far as the last section but one; the needle is passed through this section, and over the head-band twice, and finally fastened on the back. The ends of the head-band are then cut off, almost close to the silk at each end. The part

produced by working one silk over the other is called the braiding, which forms the principal beauty of the head-band, and should be ranged close down upon the leaves of the book on the inside of the band, which is easily managed. Both ends of the book having been worked in this way, the glue brush is drawn across the back of the bands, which strengthens them and keeps them in their proper places. It is now the usual practice to make a hollow back, on account of its enabling the book to open better, and also preserving the leather from cracking. The hollow back is formed by cutting a strip of cartridge paper twice the width of the back, and the same length; this is folded in half, and the back being fresh glued, one half of the folded paper is stuck on, the other half being doubled upon it. If the book is to have raised bands, they are now put on; they are formed of strips of thick leather, as wide, and at such distances from each other, as taste directs; they are glued on the loose back, and pared down at the ends, the sides being kept sharp and square. They are used to give a neat appearance to the back, and are a great improvement on the old method of sewing the book on raised bands in lieu of the sunken cords. The book is then ready for covering, with leather, if to be whole bound, or with leather and paper, if to be only half-bound. For whole binding the leather is cut about half an inch larger all round than the book, and carefully pared round the edge with a sharp knife on a piece of smooth marble; it is then pasted, folded together, and left a few minutes for the paste to soak in; it is then opened out, and the book laid on one half (the fore-edge being towards the workman), while the other half is carefully and tightly drawn over the back and uppermost cover; the covers being then adjusted at the head and foot, and pulled forward, the edges are turned down and the ends tucked in; the corners being raised are worked together, and the part so raised cut off, and the head and foot pieces being smoothed down, the fore-edge part is folded over them. The head of the book is then neatly set with the folding-stick, pressing it inwards in the joint where the corner was taken off the boards, and flatting the leather over the top of the head-bands; the form thus given in the damp state is permanently retained when dry. If the raised bands, previously described, are used, a piece of fine cord is tied round the book, (the edges being guarded with a piece of board), pressing on the upper and lower side of each band, which brings the cover close upon the back, and preserves the distinctness of the bands. For half-bound books a strip of leather is cut, about an inch longer than the back of the book, and of sufficient width to lay well over the boards; the leather corner pieces are cut of an oblong quadrangular shape. The leather being pared, the corner pieces are put on first, and the back afterwards, being worked in the same manner, and with the same care, as the whole-bound book. Marble, coloured, or other fancy paper, is cut of a proper size and form, and pasted on the sides. Smooth sheep and calf bindings are frequently ornamented by marbling or sprinkling, which is performed by throwing various colouring liquids on the cover while it is wet with water: but there is so great a variety in these processes, both of colours and patterns, that there is not space for their enumeration here; nor are they of much importance at this time, the coloured leathers having been brought to such perfection, and in so general use, as to render the employment of sprinkling, &c. of more rare occurrence than formerly. The *forwarding* of the book is now completed, and it is handed over to the finisher. The first step of the finisher is to wash the cover of the book with paste or glue water, to prevent the glaire from sinking in and staining the cover; when the sizing is dry the cover is glaired. Morocco and roan require to be glaired but once, sheep twice, and calf three times; this done, the book is ready for gilding and lettering. The places where the gilding is to be applied, are then slightly greased with palm or sweet oil, and covered with gold leaf. While lettering and gilding the back, the book is placed in the cutting-press, with the head a little elevated. The brass letters having been selected and laid in their proper order before a fire, are moderately heated; before using, they are tried on a piece of waste leather; when at the proper temperature, they are forcibly impressed upon the gold, one after the other, care being taken to keep them straight, upright, and at uniform distances—a process which requires

great practical skill. The whole of the letters being worked, the superfluous gold is wiped off with an oiled rag, to which it adheres, and when saturated, the rag is sold to the refiner, who recovers the gold which it contains. Common words of frequent use, such as *Bible, Prayer, Album,* &c. &c. are cut in one piece, and worked off at once, which greatly facilitates the process of lettering, while it insures a uniformity of appearance not otherwise attainable. Metal types are sometimes used as an excellent substitute for the brass letters; with the former, any word may be set up in a frame and worked at once, but it is essentially necessary that the types are clean and bright; there is also some difficulty in giving them the proper temperature; it would therefore be a great improvement to have brass letters cut so that they might be set up in a frame, in the same manner as the types. These would combine the beauty and accuracy of the brass letter, with the convenience of the types. The lettering having been completed, the remainder of the book is gilt with appropriate tools; these in general consist of straight lines or fillets, rolls of various breadths and patterns, and single ornamental devices, all cut in brass, and used the same way as the letters. The tools are frequently heated, and worked upon the leather without the interposition of any gold, which produces a neat and elegant contrast to the gilding; it is denominated *blind-tooling.* Whole bound books are frequently very handsomely gilt on the sides as well as the back, frequently by running a broad gold roll round the edges of the cover, and sometimes by means of corner and centre pieces, with or without lines. The following ingenious method of working these ornaments was designed by Mr. Bain, of Broad-court, Long-acre, who received the silver Isis medal and five pounds, from the Society of Arts, for his invention. The brass ornaments used for the covers are mostly triangular ones for the corners, the centre being formed by the combination of the same or other four pieces. In the ordinary manner of working, a single tool is used, which requires to be applied eight times on each cover, or sixteen times in all on each book. This occasions the loss of much time; to save the greater part of which, Mr. Bain employs four triangular blocks, capable of being fixed in a simple adjustable frame, so as to suit any sized book. The frame *a a* in the accompanying engraving, is made to hold the rods *b b* parallel to each other, and allow them to be set at any required distance apart. *c c c c* are the stamps, which are perforated to slide on the rods *b b* quite even with each other; they are fixed at the proper distances on the rods by small set screws at their back, which bind upon the rods. The frame *a a* has two long apertures, seen in *Fig.* 2, to receive the rods *b b*, which have square shoulders and fins to traverse along,

Fig. 2. *Fig* 1.



and are bound fast by the screwed nuts. *d d* shows one of the rods, with its nut separate. The small nuts *e* screw on after the stamps, to keep them from falling off the rods before they are adjusted. It will be seen that by sliding the stamps *c* along the rods *b*, and these rods along the frame *a*, they may be adjusted to suit any size and form of book. When the corners are done, if the same stamps are to be used for the centre, they may be transposed on the rods, and adjusted to suit the centre, as shown at *f f*; but it will save time, and do the work truer, to have four rods *b b* and *f f* to hold the corners and centre stamps at the same

time, for then once putting in the press does one side of the book, and all will be exactly alike, without much care on the part of the workman. If the frame *a a* is made a little wider than the thickness of the stamp on the pattern side, it might be adjusted to touch the fore-edge of the book, which would keep the pattern quite straight and equidistant on each book. By this contrivance, not only is time saved, but the patterns are registered much more accurately than they could possibly be by any other method. When very large lettering pieces, ornaments, or coats of arms, &c. are to be gilt upon the covers of books, manual pressure is inadequate to the working of them, and a press is employed, called an arming press. A very perfect machine of this description has recently been constructed by Messrs. Cope and Sherwin, of London, to which they have given the name of the "Imperial Arming and Embossing Press," which is not only capable of working every description of gilding, but is also sufficiently powerful to emboss the elegant arabesque covers, at present so much employed for ornamental bookbinding. The largest description of these covers are embossed by means of a fly-press of enormous power, but for all smaller work the imperial press is amply sufficient. In its construction it resembles the improved printing press invented by the same parties, but with the addition of a contrivance for raising or lowering the bed to suit the thickness of the book, and the platten likewise having receptacles for the heating irons. By means of a screw-and-wedge adjustment in the piston, and the rising and falling bed-plate, a considerable range, with the power of very accurate adjustment, is obtained with great facility. This machine is exceedingly simple in principle and construction, elegant in appearance, and effective in operation, and is a valuable auxiliary to the bookbinder. The book having been gilded, it is polished with a hot iron, and the edges, if coloured or marbled, are burnished with an agate burnisher: the book is then finished. If the book was only intended to be put in boards, or, as it is technically called, *boarded*, it is folded, sewed, glued, the covers cut to the size and put on, and then covered with coloured paper, the edges of the book remaining uncut. *Extra boarding* has stouter boards than the former, and is finished with rather more care; sometimes the edges are cut, and the book covered with a neat coloured and embossed or printed cloth, which gives a very neat appearance at a cheap rate.

Vellum Binding, as was before observed, is the term applied to the binding of every species of account book. The first step is to fold and count the paper into sections, which in foolscap generally consists of six sheets; above that size, of four sheets, which are sewed upon strips of vellum. Small books, up to foolscap folio, usually have three strips; above that size the number is increased. Account books are sewed much in the same way as printed books, except that vellum slips are used in lieu of the cords, and a much stronger thread and wax are employed. After sewing, the first ruled leaf at each end is pasted to the waste paper, and the marble paper lining introduced; the back is then glued in the usual manner. When the glue is dry, the fore-edge of the book is cut, and the back rounded, a deeper hollow and rounder back being formed in account books than in printed ones. The two ends are then cut, and the edges marbled. The head-bands are worked on a slip of stout board, as before described, care being taken in this instance to form a deep narrow, rather than a round band. Strong pieces of canvass or buckram are then glued at the top and bottom of the back, and between each of the vellum slips. A hollow back is prepared by taking a slip of milled board, about a quarter of an inch wider than the back of the book, and soaking it in water; it is then glued on both sides, and left in this state for about ten minutes: having been laid on a sheet of paper, a roller corresponding in dimension with the back of the book is placed upon it, and the whole worked backward and forward on the roller, which gives the milled board a semicircular shape; it is then dried hard before the fire. Another method, which is a very good one, and frequently adopted, consists in taking a roller (an assortment of the most useful sizes being kept for the purpose), and winding round it thick paper and wrappers well pasted, until the requisite thickness is obtained; the roll is then thoroughly dried and divided longitudinally, which forms two good firm semicircular backs. Milled

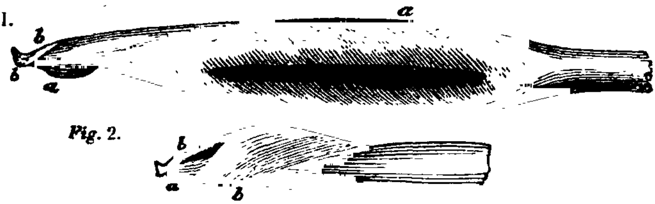
boards of a thickness proportionate to the size of the book are then taken, and the fly-leaf of the book being pasted, the board is laid on in its proper place; the same course is also pursued with the other side. It is customary with large books to use two thin boards pasted together, instead of one thick one: in this case the vellum slips on which the book is sewn, are inserted between them, which adds greatly to the strength of the binding. After the boards have been squared, the back, formed in the manner described above, exactly fitting the back of the book, is placed upon it, and a piece of canvass being cut sufficiently large to extend half the width of the back on one side of the book to the same distance on the other side, is glued on the boards and over the back, which contributes to strengthen the book, and hold the hollow back firmly in its place. The back is sometimes formed of sheet iron, which, in large books, is an improvement: this kind of back was first introduced by Mr John Williams, who took out a patent for his invention. The book is now ready for covering: the leather for the cover is carefully pared all round, and put on as before described under the head of Bookbinding. The covers mostly used by vellum-binders are forril and vellum, white and coloured; smooth and rough calf and sheep; basil, smooth and grained, and Russia; in any of which books may be either whole or half-bound. Forril and vellum covers are lined with paper and pressed smooth; when dry, they are fitted on the back, and creased in the joints; the boards are then pasted, and the covers pressed on them; when dry, the edges of the cover are pasted and turned in, and the book again pressed; the cover is then washed with a sponge and paste-water, and then ruled off. If the cover is rough calf or sheep, it is dressed with pumice-stone and a clothes brush. Smooth calf, basil, &c. are glaired and polished as described in bookbinding. Rough calf books are usually ornamented by passing a roller round the edges and sides of the cover, with sometimes an ornament added; for this purpose, the tools must be used nearly red hot. To increase the strength of large books, they sometimes have, in addition to the leather or vellum cover, bands of Russia leather, which ar worked on with thongs of vellum, and give the book a very neat appearance. The lettering of account books is precisely the same as before described.

BORACIC ACID. An acid which, combined with soda, forms borax, or borate of soda. As obtained by the action of sulphuric acid upon a solution of borax, it is in the form of thin irregular hexagonal scales, of a silvery whiteness, having some resemblance to spermaceti, and the same greasy feel. By fusion, it is converted into a hard transparent glass, which is used in the composition of false gems.

BORAX. A compound of soda and boracic acid, and of considerable use in various metallurgic operations. It enters into the composition of reducing fluxes, and is of the greatest use in analysis by the blow-pipe. It is more especially used in soldering; it assists the fusion of the solder, causes it to flow, and keeps the surface of the metal in a soft clean state, which facilitates the operation. It may also be applied with advantage in glass manufactories; for when the fusion turns out bad, a small quantity of borax re-establishes it.

BORING BIT. A tool or instrument used for making aper ures in wood, metal, or other hard substances. They are of various shapes, too common to

Fig. 1. *Fig.* 2.



workmen to need description; but one of a very peculiar and effective kind, represented above, was brought from Germany by Mr. Donkin, and is described in the *Transactions of the Society of Arts*. *Fig.* 1 is a front view of the boring

bit; *a a* the cutting edge; *b b* a thread or fin, winding round the back, which acts as a screw to draw the bit into the wood. *Fig.* 2 is a side view of the same. The instrument is very simple, enters the wood rapidly, and forms a clean hole.

BORING MACHINES. A name usually confined to machines for giving a perfect form to metallic cylinders, as pump barrels, blowing machines, &c., which machines differ from lathes in the circumstance of the tool revolving, whilst the work either remains stationary, or advances in a right line. In all boring machines, a long bar, called the boring bar, passes through the cylinder, and revolves in bearing or supports. To the boring bar are fixed a number of steel cutters, which, as they revolve, receive also a motion endways, and are carried through the whole length of the cylinder to be bored. The boring machine used for the smaller and coarser description of pump work is extremely simple in its construction. It consists of a boring bar, somewhat more than double the length it will ever be required to bore, and supported by bearings distant from each other not quite half its length. A mortise is cut through the boring bar, and the cutters are firmly fixed in it by wedges or keys. Into a socket in one end of the bar is keyed a screw about half as long as the bar, and its outer extremity supported in a nut fixed in a standard, the axis of the screw and of the bar exactly coinciding or forming a continuous right line. The bar being passed through the cylinder to be bored, and the cylinder being secured upon beds so as to be concentric with the bar, the latter is turned round either by a winch or a wheel, fitted upon the end opposite the screw; and the screw making a revolution in its nut for each revolution of the bar, advances the bar and cutters through a corresponding space along the cylinder. For cylinders of larger diameter, and requiring more accuracy in the boring, a different construction becomes necessary. The cutters are fixed upon the circumference of a short cylinder, termed the cutter-block, through which the boring bar passes; and either the two, as they revolve together, receive a slow end motion, or the cutter block only advances whilst the bar revolves, but remains stationary. There are various modes of advancing the cutters in either case. The following extremely ingenious arrangement, in which the boring bar and cutter advances, carrying with it the cutter block, is, we believe, the invention of Mr. Murray, of Leeds. Upon the extremities of a horizontal bed of cast iron are fixed two upright standards, supporting brass bearings, in which the boring bar turns. Upon the cast iron bed are two blocks, for supporting the ends of the cylinder, with arrangements for adjusting it, so that its centre shall coincide with the axis of the boring bar, and to these blocks the cylinder is firmly secured by straps or chains. The boring bar is turned perfectly cylindrical, and has a groove extending from one end more than half its length. The cutter block, which is a disk nearly of the same diameter as the cylinder, and armed at the circumference with a number of steel cutters, is firmly keyed upon the bar in the space lying between the standard. Upon the grooved end of the bar, and close to the outer face of the standard, is the driving wheel, the centre of which is bored of the same diameter as the bar, so as to allow the latter to slide within it freely, but without shaking, whilst the wheel is prevented from turning without causing the bar to revolve, by means of a steel key, fitting into the groove in the bar, and into a similar groove in the boss of the wheel. A screw, half as long as the bar, is supported at the outer end by a nut, which is at liberty to turn in bearings placed upon a vertical standard, whilst the inner end of the screw, formed into a square, is keyed into the end of the boring bar. Parallel to the screw is a small shaft, having at one end firmly fixed a small wheel geering into another small wheel fixed upon the face of the nut, whilst another wheel, which turns with the shaft, but is at liberty to slide along it, geers into a wheel fixed upon that end of the bar to which the screw is attached. The operation of the machine is as follows: The driving wheel turns the boring bar, and with it the screw. Now if the nut were to remain at rest, the screw would advance through a space equal to the rake of the screw, and draw after it the boring bar; but if the nut, by properly proportioning the diameters of the small wheels, revolve in the same direction as the cutter bar, but with a less velocity, then the cutter bar and screw will advance through a space

proportioned to the difference between the velocities; so that if the speed of the cutter bar exceed that of the nut by one-tenth, the screw and cutter bar will advance through only one-tenth of the rake of the screw. In the boring machines for cylinders of very large dimensions, the cutter block usually advances, whilst the boring bar remains stationary. In these machines the boring bar is sometimes placed horizontally, but we think a vertical position preferable, as the weight of a long horizontal bar occasions a tendency to sink in the middle; also when the bar is vertical the cylinder is more easily fixed, and the borings, instead of clogging the cutters, fall upon the base plate. The annexed engraving represents a vertical boring machine of a new and improved construction, which was erected in an extensive engineering establishment, and of which we believe no description has yet appeared in print. Upon a foundation

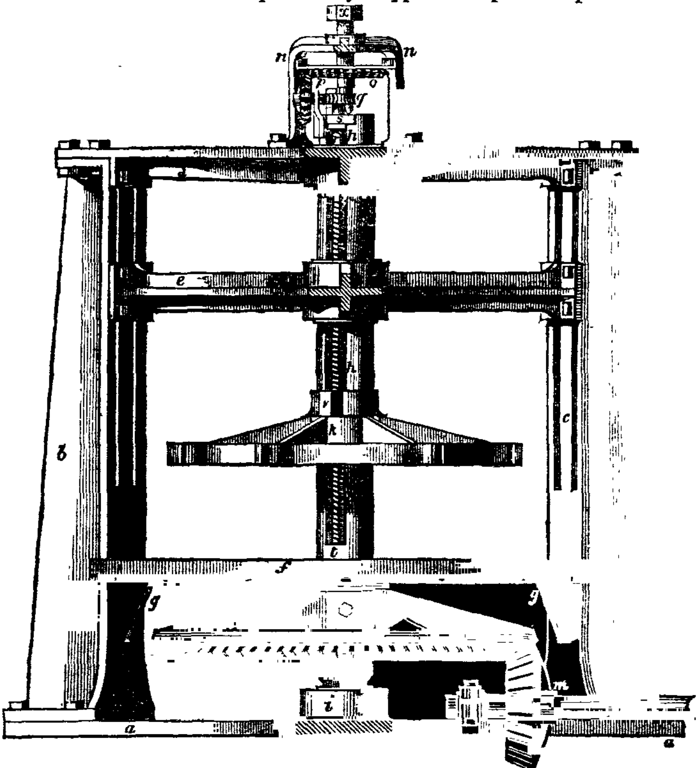
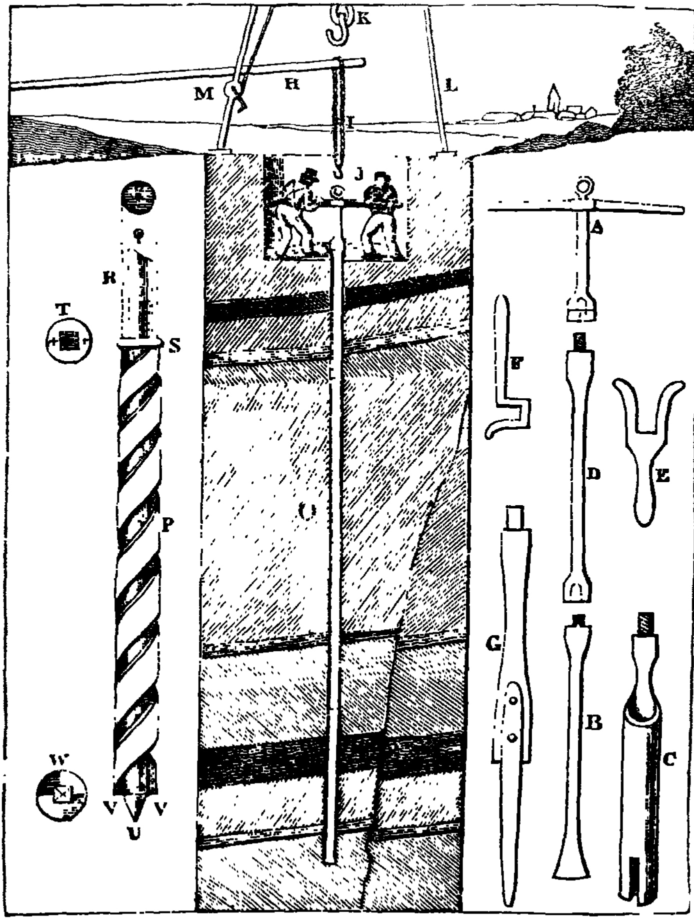


plate *a* are bolted three standards, of which only two *b c* are shown, the third being removed to show the boring bar. These standards support the top plate *d*, formed of three radiating arms; *e* is a steadying bridge, which may be set at any height, by means of screws passing through the mortises in the standards, and secured at the back by nuts; *f* is the bed to which the work is bolted, for which purpose it has a number of mortises radiating from the centre; it is supported by brackets *g g* projecting from the standard; *h* is the boring, turning in collars in the top plate *d* and in the bridge *e*, and supported by the step *i*; *k* the cutter-block, which is a stiff wheel, bored out accurately to receive the boring bar, so as to slide upon it easily, yet without any shake. On the periphery of the block are eight notches, in which the cutters are fixed by wedges; *l* a bevelled wheel, and *m* a pinion by which a rotatory motion is given to the boring bar and cutter block, the latter being made to advance along the former by the following means: Upon the top plate *d* is a small triangular

frame n, to which is bolted the bevelled wheel o, in which another wheel p geers. p revolves in bearings fixed upon the head of the boring bar, and has upon its axis an endless screw driving the worm-wheel q, which is fixed upon a long screw r, lying in a mortise cut in one side of the boring bar. This screw turns in collars s and t, and works in a nut fitting into the mortise in the boring bar, and attached to the cutter block at v; the bevelled wheel p is 10 inches in diameter, and the wheel o 16 inches; therefore in ten revolutions of the boring bar, the wheel p will perform sixteen revolutions on its axis, and at each revolution the endless screw upon its axis will move the worm wheel q one tooth forward; and as the worm wheel has sixteen teeth, in ten revolutions of the boring bar the screw r, to which the worm wheel is attached, will make one turn, and will advance the cutter block through a space equal to the space between the threads of the screw. x is a strong spindle screwed into the frame n, and formed with a conical point, which is received into a conical steel bush in the centre of the head of the boring bar, and prevents the bar from rising.

Boring the Earth for Water. An economical process has been practised of late years for obtaining water from great depths, without the expense of sinking a well. This process consists simply in boring the earth with an auger and other proper instruments, to a considerable depth; and in most situations water will flow either to the surface, or to within a short distance from it; in some places it has been known to spout to a considerable height above it. It has long been a question whence these springs derive their supply, and how they acquire the power of ascension. The most natural supposition is, that they are connected by subterraneous channels with some elevated reservoir; but this explanation is not altogether free from difficulty. These "Artesian wells," as they are termed, are to be met with in the middle of extensive plains, at a great distance from any hills, and upon the sides of mountains, which require to be bored to a great depth before the water is attained. At Mount Rouge, at Paris, 80 feet above the level of the Seine, there is one of these wells 315 feet deep. If, therefore, these wells be supplied from an elevated reservoir, it must lie at a very considerable distance from the wells. The implements made use of in the process are extremely simple, and are represented in the engraving on the following page. A is the cross handle of the borer, for two men to work; B the chisel borer, which is made to screw into A; C the auger, which also screws into A; D a lengthening rod, having at one end an external screw fitting the screw of A, and at the other end a hollow screw like that in A, so that all the instruments which fit into A may, as occasion requires, be screwed into the lengthening piece D. A great number of these lengthening rods are kept in readiness, which can be screwed one into the other, so as to descend to the depth of several hundred feet. E a forked iron, used to lay across the hole to support the rods at the joints, while the pieces are being screwed and unscrewed; F a spanner, used to screw on and unscrew the various tools and lengths of rods; G a clearing chisel, with a probe or piercer attached to guide it; H a spring bar, used to produce a vibrating up-and-down motion to the chisel, when used to peck away hard or rocky ground; I iron chain to connect the cross handle of the tools to the spring bar; J two men at work, boring with the chisel; K the lower pulley of a pair of blocks, suspended to a pair of shears or a triangle above; L the shears or compasses; M winch or crane, to work the blocks when great weights are to be raised; O three lengths of rods, and the chisel in the act of boring,—perforation about 42 feet. As a preparatory measure, a large hole is *usually* dug to the depth of seven or eight feet; at the bottom of which a floor is formed, by means of some planks, for the men to stand on and pace round whilst using the instruments. If the earth is very soft, the only tool requisite is the auger C of three or four inches diameter, which is screwed into the cross handle A, and the perforation is easily effected by the mere turning of it round by two men, as shewn in the drawing. When the auger has penetrated to nearly the depth of the tube, it is withdrawn, and cleared of its contents. It is then let down again, and the perforation is in this manner continued to the whole length of the instrument. To proceed to a greater

depth, the lengthening rods, before described, are put in requisition. The auger is detached from the handle by unscrewing it; a piece of rod D is screwed in its place, and the auger screwed on to the rod. With the instrument thus lengthened seven or eight feet, the boring is renewed by means of the auger, as long as the earth is found to be sufficiently soft and yielding. Whenever it proves otherwise, or hard and rocky, the auger is detached from the rod, and the chisel B, which is from three to four inches in diameter at its edges, is screwed on in its place. If the ground is not *very* hard, the boring may be continued



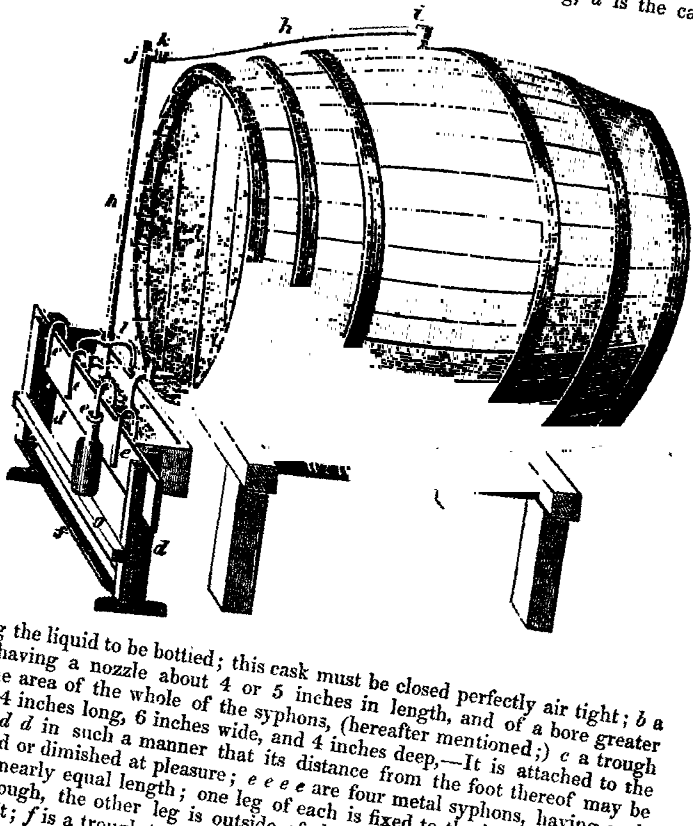
by the chisel, by the workmen pressing upon it as they turn it round; but when the earth is too hard to be operated upon by a chisel in this way, recourse is had to *pecking*, which is done by lifting up the instrument, and striking it against the opposing substance till it is chipped away, or reduced to powder to a certain depth. The rod and chisel are then again drawn up, and the auger substituted for the chisel, for the purpose of extracting the pulverized stony matter contained in the hole. The chisel and auger are thus employed alternately where the ground is hard and stony, the one for chipping away or pulverizing, and the other for clearing out. As the perforation deepens, the process of pecking

becomes very laborious; recourse is therefore had to the spring bar H, which is a strong pole placed horizontally over the well, at the height of three or four feet from the ground, with one end inserted into a post or other stronghold. The chain I is attached to this bar, and the borer is suspended by the handle to the hook of the chain which supports its weight; a slight vertical motion is then given to the bar by the workmen, which causes the chisel to peck away with great rapidity. As the weight of the implements becomes too great to be drawn up by hand, when the boring has proceeded to a great depth, the mechanical aid of a pair of pulley blocks K is used for the purpose, which are usually suspended from a triangle or a pair of shears fixed over the hole. The higher these shears are the better, so as to enable the workmen to raise a great length of rod, without unscrewing at each joint of the rod. In the manner described the boring proceeds, changing the tools from time to time for such as may be best suited to cut through the various strata, whether of a soft, indurated, or stony texture, until the main spring is arrived at, when the water flows up the newly-formed tube to the height of the distant spring from which it is derived. If that be at a greater altitude than the surface of the earth bored, the water rises above the ground, producing a perpetual fountain; on the contrary, if it be below the surface, a well must be sunk of some capacity, down lower than the level of the spring; into this well the water flows and forms a reservoir, and may be raised to the surface by means of a pump. The earth is sometimes bored by the before-mentioned simple apparatus to the depth of two, three, or four hundred feet, either for the purpose of obtaining water, or to ascertain the presence of minerals. To carry on the operation at these great depths, a corresponding increase of power is required, which is obtained in a variety of ways. When the hole is bored, a pipe of cast iron or other metal is forced down it, to prevent its being filled up again by the falling in of the surrounding earth, and likewise to keep out the impure land springs which might taint the water. Although the process conducted as above described is extremely simple, it is very tedious and laborious, owing to its being necessary to withdraw and unscrew the whole of the rods each time the earth requires to be removed from the boring tool, and to screw them together again upon returning the borer. To obviate these inconveniences the editor has suggested a method by which the operation may be carried forward at great depths, and the earth extracted without withdrawing the rods, by which also full three-fourths of the time and labour may be saved. The means by which it is proposed to effect this desirable object are as follows: An auger is to be made with a spiral worm winding round a cylinder which forms its centre. The cylindrical part is not to be solid, but perforated throughout its whole length by a square hole of two or more inches diameter, for the purpose of receiving within it an iron bar of the same figure and admeasurement. The bar will thus serve the double purpose of a spindle or shaft to work the auger or cause it to bore, and of a slide upon which the auger may be drawn up with facility to the surface from very great depths in a few seconds of time, its contents be discharged, and the auger be let down again as quickly, to proceed in the perforation of a fresh portion of earth. That a part of the contents of the spiral auger may not fall out when being drawn up, the worm or thread is not to be left open, but is to have a perpendicular border, raised upwards at right angles to the plane of the thread; the aperture between the upper edge of this border and the next thread is left open for clearing out the auger with facility. The construction will be easily understood by referring to the engraving, in which P represents the exterior of the spiral worm or auger; Q the square iron bar passing through the square tube of the auger; R chains to draw up the spiral worm along the bar; S top plate, to which the chains are attached; T upper view of the plate, showing the square hole through which the bar passes; U angular point of the square bar; V V cutting edges of the auger; W under side view of the bottom cutting parts of the auger. Various kinds of tools may be attached to the bottom of this auger so as to peck, &c.

BOTTLE. A vessel with a narrow mouth or aperture, used to contain liquids; and usually composed of glass or earthen ware. Under these two

heads will be found a description of the process of manufacturing them; we shall, therefore, in this place, briefly notice some inventions connected with them, and which we could not introduce under separate heads.

The first is Masterman's patent apparatus for bottling wine or beer, which, as usually performed, is a tedious and wasteful process; but by the apparatus which we are about to describe, the bottles may be filled uniformly to a precise point, as fast as they can be changed, without the necessity of any examination on the part of the workman. In the annexed engraving, *a* is the cask con-

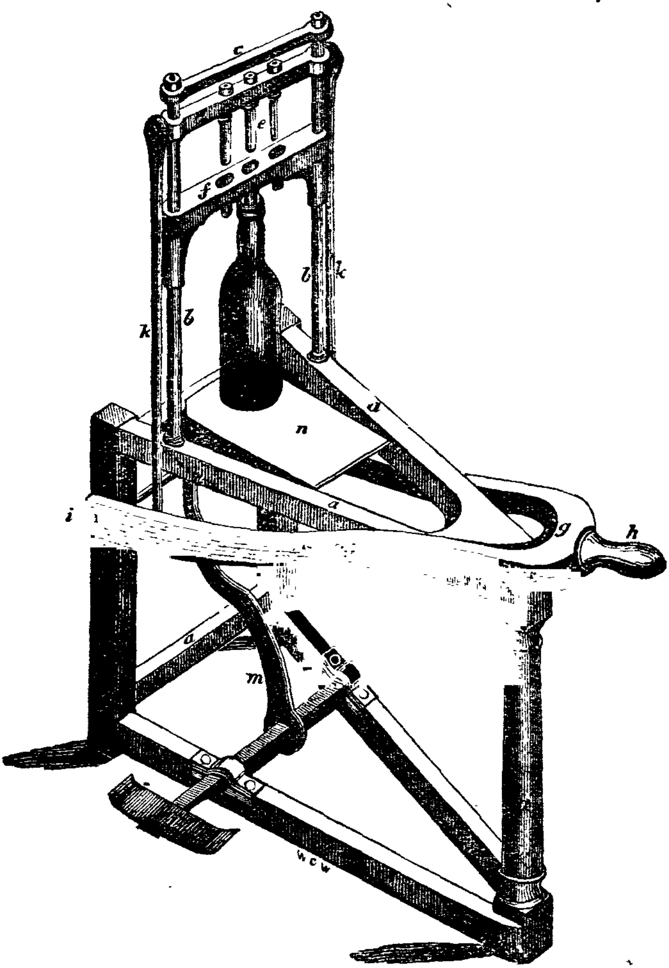


taining the liquid to be bottled; this cask must be closed perfectly air tight; *b* a cock, having a nozzle about 4 or 5 inches in length, and of a bore greater than the area of the whole of the syphons, (hereafter mentioned;) *c* a trough about 14 inches long, 6 inches wide, and 4 inches deep,—It is attached to the frame *d d* in such a manner that its distance from the foot thereof may be increased or dimished at pleasure; *e e e e* are four metal syphons, having each a leg of nearly equal length; one leg of each is fixed to the inside of the front of the trough, the other leg is outside of the trough about 3 inches from the front of it; *f* is a trough to catch the liquid which may be spilt whilst changing the bottles; it can be slided up and down the frame, and has a rail *g* for the bottles to stand on while filling; *h h* represents what the patentee terms an air tube; the cross piece *i* is of solid brass, bored only so high as to pass the end of the tube soldered into it. The horizontal part of the tube is made of pure tin, on account of its flexibility; it is connected to the vertical part by a union joint at *k*; *l* is an iron brace placed across the trough, to retain the air tube firmly in its proper situation. The mode of using the machine is as follows; the trough *c* is fixed so high in its frame, that the bottom comes within an inch of the orifice of the cock, and the air tube is fixed in the brace, so that its lower orifice may be at least one inch above the orifice of the cock, and at least one inch below the top of the trough, and the other end of the air tube is driven air tight into a hole either through the bung of the cask, or through a hole made for the purpose in the cask above the surface of the liquid therein. Upon opening the cock, the liquid flows

into the trough until it rises so high as to close the orifice of the air tube, when the air no longer having admission to the cask, the liquor ceases to flow. The syphons are then put in action by exhausting the air out of them successively by the mouth applied to a bent tube, one end of which is placed against the syphon so as to form an air tight tube within it. The outer end of each syphon, as it is brought into action, is inserted in the neck of a bottle, and the point to which the bottles are to be filled is brought to a level with the orifice of the air tube, the rail *g* being adjusted so as to retain the bottles at this elevation. As the bottles fill, the surface of the liquid in the trough sinks until it descends below the orifice of the air tube, when the air rushes into the cask, and the liquid recommences flowing; and thus by this alternate action, the liquid in the trough is always preserved nearly on a level with the orifice of the air tube. As each bottle fills, it is withdrawn quickly from the syphon and replaced by an empty one; but if the bottles are suffered to remain, they will never fill higher than the level of the orifice of the air tube, which it has been shown is the level to which the liquid in the trough is confined. Another method of maintaining the liquid in the trough at always the same level is described in the specification, which we think is upon the whole preferable to that described above. It consists in substituting for the air tube a species of valve, adapted to the lower orifice of the cock, and regulated by a float on the surface of the liquid in the trough, so that as the liquid rises in the trough, the float also rises, and causes the valve to shut when the surface of the liquid has attained its proper level; and as the level sinks the float also sinks and opens the valve, causing the liquid to flow again. When the float and valve are substituted for the air tube the cask must have vent.

A most useful appendage to the foregoing apparatus, is the patent machine for corking bottles, invented by Mr. J. Masterman, by the use of which all risk of breaking the bottles is avoided; the necessity of biting the corks, (a practice highly injurious to the health of the workmen,) is done away with, the bottles are corked in a very superior manner, and the whole operation conducted with cleanliness, economy, and unprecedented dispatch. The following is a description of the machine, (with reference to the annexed engraving,) and of the manner in which it is worked: *a a a a* represents the frame, *b b* two vertical guide rods, connected at top by the bridging piece *c*; *d* a cross head sliding upon the upper ends of the guide rods, and connected by the side rod *k k*, to the levers *g g*, which are united at the handle *h*, and which have their fulcrum at *i*. In the cross head *d* are secured by nuts on its upper face three cylindrical metal bolts, termed by the patentee "impellers;" *f* is a cross piece of wood firmly fixed to the guide rods, at such distance from their tops, as that when *d* is raised close to the bridging piece *c*, there may be a space between the bottom of the impellers, and the top of *f*, at least equal to the length of a cork. In *f*, are fitted three conical metal tubes, immediately beneath, and concentric with, the impellers. These tubes have their mouths larger, and their lower apertures smaller than the corks, and are of three different sizes, which is sufficient to meet the variations in the size of the bottles, whether for wine or beer; *l* is a treadle which, by means of the iron rod *m* fixed to its axis, raises and depresses the wedge *n*; this wedge slides on a cross piece of wood, (firmly fixed to each side of the frame *a*,) in such a manner that the upper surface of the wedge is always preserved in a horizontal position; a loop of iron is fixed below its thicker end, and in it the upper end of the bar *m* works. To use the machine, the workman seats himself beside it with his right foot on the treadle; he then places a bottle so that its mouth is under, and in contact with, that tube which is of the proper size for introducing the cork into it, and retains the bottle in that position by raising the wedge against its bottom by means of his foot acting on the treadle; then raising the impellers by means of the lever, he puts a proper sized cork into that tube which is in contact with the mouth of the bottle, he depresses the lever, by which action the cork is forced by the impeller into the neck of the bottle; then lowering the wedge by the pressure of his foot on the treadle, he removes the bottle, which completes the operation. This we think is a most meritorious invention, and one deserving of general adop-

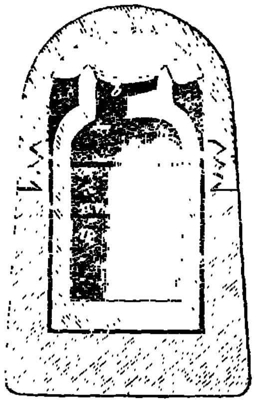
tion. The patentee states, that "more than half the time is saved, owing principally to the compression of the cork, and the impelling it into the bottle being effected at one operation or motion of the lever. Twelve bottles have been corked in one minute by way of experiment, and thirty dozen in an hour; but one workman could cork with ease at the rate of five and twenty dozen per



hour throughout the day. The bottles also are better corked, partly owing to the corks being compressed and compacted, instead of being crushed or broken, as in the common methods; and partly from the corks, at the moment of entering the bottle, being subjected to a pressure both on their tops and sides, which causes them to become firmer and closer in the bottles, than when driven in after being crushed by any of the common methods.

A patent has been obtained by Mr. H. Berry for forming bottle stoppers of India rubber with the view of preventing the escape of volatile and other fluids, which cannot be well retained by the usual means of stopping. To effect this object several methods are described by the patentee in his specification; that which is shewn in the engraving represents the section of an ink bottle for

the pocket. *a* is the glass bottle with the extremity of the neck ground to an angular edge, where it is brought into contact with a disc or button of caoutchoc *b* fixed into the top of the exterior case, which is of hard wood; the top being screwed down as shewn in the figure, the glass edges of the bottle are forced into the elastic substance, so as to form a close and perfectly air-tight stopper. For volatile salts, the patentee uses the ordinary glass stoppers, and applies a collar of caoutchoc under a projecting flange of the stopper, which presses upon the upper surface of the neck.



BRAKE. In Mechanics, a contrivance for retarding or arresting machinery in motion, by means of friction. It generally consists of a simple or compound lever, pressing forcibly upon the periphery of a broad wheel fixed upon one of the shafts or axes of the machine.

BRAN. The inner husk or skin of wheat, which is separated from the flour by the boulting machine. It is employed in the manufacture of starch, and also by dyers in making what they call the sour water with which they prepare their several dyes.

BRANDY. The spirituous liquor obtained by distillation of wine, and which, by further concentration, may be converted into alcohol. The best brandy is made in France; that made in Spain and Portugal is distinguished by an acrid and disagreeable taste.

BRASS. An elegant yellow-coloured compound metal, consisting of copper combined with about one-third of its weight of zinc. The best brass is made by cementation of the ore of zinc with granulated copper. See Alloy.

BRAZIL WOOD. A red-coloured wood, chiefly used in the process of dyeing. The tree that affords it is the growth of the Brazils, in South America. The wood is capable of a good polish, and is so hard that it sinks in water Its colour is pale when newly cut, but it becomes deeper by exposure to the air. The various specimens differ in the intensity of their colour, but the heaviest is reckoned the most valuable. It has a sweetish taste when chewed, and is distinguished from red sanders or sandal, by its property of giving out its colour to water, which this last does not. If the Brazil wood be boiled in water for a sufficient time, it will communicate a fine red colour to that fluid. The residue is very dark coloured, and gives out a considerable portion of colouring matter to a solution of alkali. Alcohol extracts the colour from Brazil wood, as does likewise the volatile alkali; and both these are deeper than the aqueous solution. The spirituous tincture stains warm marble of a deepish red, inclining to purple, which on a greater heat becomes violet; and if the stained marble be covered with wax, and considerably heated, it changes through all the shades of brown, and at last becomes fixed of a chocolate colour. The colours imparted to cloth by Brazil wood are of little permanence. A very minute portion of alkali, or even soap, darkens it into purple. Hence paper stained with it may be used as a test of saturation with the salts. Alum added to the decoction of this wood occasions a fine crimson red precipitate or lake, which is increased in quantity by the addition of alkali to the liquor. The crimson red colour is also precipitated by muriate of tin, but it is darkened by the salts of iron. Acids change it to yellow, from which, however, solution of tin restores it to its natural hue. A strong decoction of Brazil wood, with as much alum as it can dissolve, and a little gum, forms a good red ink; some manufacturers add cochineal to give the colour more permanence and brilliancy: good red ink may, however, be made without this addition.

BREAD. Various preparations of farinaceous substances bear this denomination; but those which are chiefly used in this country may be distinguished into three principal kinds. In the first, called *unleavened bread*, either flour and water alone are mixed, or with the addition of some other substance, such

as butter, eggs, sugar, and afterwards baked, by which the mass is reduced into a solid state, sometimes flakey, but never cellular or spongy. Biscuit, or sea-bread, is of the unleavened kind, for the process of making which see BISCUIT. In the second kind of bread, called *leavened bread*, the flour and water being mixed together, is either left for some hours in a thin and almost liquid state to ferment, that the saccharine matter contained in the flour may be spontaneously changed into alcohol and carbonic acid gas, which expand by the heat of the oven, and render the bread vesicular or spongy. Although this intestine change will take place naturally at the temperature employed in the vinous fermentation, it is usual to add certain substances, termed *ferments*, of which the barm of beer, or yeast, is preferred, where it can be obtained. These accelerate the fermentation of the dough, and cause it to take place simultaneously throughout the whole mass of dough. In the third kind of bread, a vesicular appearance is given to it by the addition to the dough of some ammoniacal salt, (usually the sub-carbonate,) which becomes wholly converted into a gaseous substance during the process of baking, causing the dough to swell out into little air vessels, which finally bursting, allow the gas to escape, and leave the bread exceedingly porous. Mr. Accum, in his *Treatise on Culinary Poisons*, has stigmatized this process as "fraudulent," but, in our opinion, most unjustly. The bakers would never adopt it but from necessity: when good yeast cannot be procured, it forms an admirable and perfectly harmless substitute; costing the baker more, it diminishes his profit, while the consumer is benefited by the bread retaining the solid matter, which by the process of fermentation is dissipated in the form of alcohol and carbonic acid gas. To persons unacquainted with the nature of the flour of wheat, it is necessary to state that it is composed of three distinct substances, which are easily separable by art: first, a mucilaginous saccharine matter, soluble in cold water; much starch, which will scarcely combine with water without the aid of heat; and an elastic adhesive grey substance, called gluten, which is insoluble in cold water, alcohol, oil, or ether, and resembles an animal substance in many of its properties. To the gluten in wheat flour is supposed to be owing its property of making so tenacious a paste, and its peculiar facility of rising or expanding by the addition of leaven. From the flour of barley, rye, oats, or potatoes, no gluten has been extracted, probably from their containing too small a quantity; and as these substances are very difficult of fermentation by any of the ordinary processes, it has been supposed that the presence of gluten is the cause of fermentation. It is, however, more reasonable to suppose that the tenacious dough formed by the admixture of gluten prevents the escape of the gaseous products of the fermentation, and that these, by their expansion, swell the dough into a vesicular mass, producing what is technically called light bread. M. Beccari, of Bologna, and Dr. Cullen, inform us that by the addition of gluten to barley and potatoes, they produced better bread from each than could be obtained without this addition. Parmentier asserts that bread may be made from potatoes alone; but Mr. Edlin and Dr. Pearson, two very enlightened experimentalists, state decidedly that this root cannot be fermented so as to make bread, without the addition of wheaten flour; and that no farinaceous substance can be made into good bread that has not the three constituent parts of wheat before-mentioned: for if to the starch of potatoes some of this glutinous substance be added, with yeast and water, it will not form a bread, owing to the absence of the saccharine or sugary extract on which the process of fermentation depends, and which, if this last substance be added, even in a concentrated state, will immediately commence. Although we have no knowledge of Parmentier's process, we believe that his assertion is perfectly correct; for since the experiments were made by Mr. Edlin and Dr. Pearson, the farina of potatoes has been converted, on a great scale, into sugar and alcohol; and it has been long known that potatoe starch may be transformed, by the application of dry heat, into a species of tapioca, of great tenacity and elasticity. With such materials, we should imagine the skill of a Parmentier would hardly be necessary in order to make good bread. In the making of leavened bread without the addition of any article for exciting the speedy fermentation of the paste, a

great deal of attention and skill are requisite. The spontaneous decomposition is extremely slow; the various parts of the mass are differently affected, according to the humidity, the thickness or thinness of the part, the vicinity or remoteness of fire, and other circumstances less easily investigated. The saccharine part is disposed to become converted into alcohol; the mucilage has a tendency to become sour and mouldy; while the gluten, in all probability, verges towards the putrid state. An entire change in the chemical attractions of the several component parts must then take place in a progressive manner, not altogether the same in the internal and more humid parts, as in the external parts, which not only become dry by simple evaporation, but are acted upon by the surrounding air. The outside may therefore become mouldy or putrid, while the inner part may be only advanced to an acid state. Occasional admixture of the mass would of course not only produce some change in the rapidity of this alteration, but likewise render it more uniform throughout the whole. The effect of this commencing fermentation is found to be, that the mass is rendered more porous by the disengagement of elastic fluid, which separates its parts from each other, and greatly increases its bulk. The operation of baking puts a stop to this process, by evaporating great part of the moisture which is requisite to favour the chemical attractions, and probably by still further changing the nature of the component parts. Bread thus made will not possess the uniformity which is requisite, because some parts may be mouldy, while others are not sufficiently changed from the state of dough. The same means are used in this case as have been found effective in promoting the uniform fermentation of large masses. This consists in the use of a leaven or ferment (as before mentioned), which is usually a small portion of dough of the same kind, but in a more advanced stage of the fermentation. To prepare an original leaven, take 8 oz. of flour, and two pints of blood-warm water, and as soon as the sponge begins to rise on the second day, add 1 lb. of flour, and four pints of water; and thus proceed for a day or two more, when a mixture will be obtained, which, being added to a quantity of flour and water intended for bread, will determine the fermentation to take place throughout the mass in three or four hours. It is only under peculiar circumstances that a recourse to an original ferment is necessary; for this ferment having been once obtained, and the dough nearly ready for baking made from it, the fermentation of the next parcel of bread is readily put in action by reserving some of the fermented dough or leaven, as it is called, and using it for that purpose. To preserve this leaven from becoming sour, several methods are adopted. In the north of England, the leaven for the next week's baking is kept fit for use by being buried a few inches deep in a sack of flour. In Italy it is said to be kept fresh even for three months by being buried deep in flour. The French, if they intend to use the leaven in a few days, keep it in a warm place between two bowls, and add every day as much flour as the leaven weighs, and a sufficient quantity of water to restore the original consistence; but if it is not to be used for a week, or longer, the scrapings of the kneading trough are cut into small pieces, dried by a gentle heat, and when wanted, rubbed down with warm water. It appears from the Scriptures, that the practice of making leavened bread is of extreme antiquity; but the addition of the scum that arises in the vinous fermentation of beer, called barm or yeast, seems to be of modern date, and is now in general use throughout the north of Europe. In this country this yeast is generally used in the proportion of a pint to a 100 lbs. of flour, and is dissolved in the first parcel of water with which the flour is mixed, and no leaven is used; but at Paris, and other great towns in France, the dough is made first with leaven, and a little yeast is added to the last parcel of water, merely to increase the sponginess of the bread. Although we have given under the head Barm an account of the nature of this useful ferment, and various modes of preparing it, we shall here add some further information which more immediately appertains to the manufacture of bread. If yeast is not to be purchased, original yeast may be obtained by boiling a quarter of a peck (3½ lbs.) of meal for eight or ten minutes in three pints of water, and pouring off two pints, which is to be kept in a warm place; the fermentation will commence

in about thirty hours, at which time four pints more of a similar decoction of malt are to be added, and when this ferments, another four pints are to be added, and so on, until a sufficient quantity of yeast is obtained. In Edinburgh the bakers multiply their yeast daily, by mixing 10 lbs. of flour with two gallons of boiling water, and covering it up for about eight hours. Two pints of yeast, made the day before, are then stirred in, and in about six or eight hours as much new yeast will be generated as will suffice for 420 lbs. of flour. When original yeast is prepared from malt, the fermenting wort may be added to the flour as well as the yeast, according to Mr. Stock, whose patent substitute for yeast is merely wort in a state of fermentation. This wort is made from 2 lbs. of malt, ½ oz. of sugar, and 1 oz. of hops, to each gallon. Two gallons of this wort are sufficient for 12 bushels of wheaten flour. The Hungarians prepare a similar ferment for keeping all the year, by boiling in water in the summer wheat bran (obtained in grinding for household flour,) along with hops; the decoction soon ferments, and then a sufficient quantity of bran is flung in to drink up all the liquid, and allow it to be formed into balls, which are dried in a gentle heat. When wanted for use, some of these balls are broken, and boiling water poured upon them, which, after some time, is strained off and used to make up the dough. In like manner, the Romans prepared their ferment by drawing off in vintage time a quantity of grape juice, while at the height of its fermentation, pouring into it a sufficient quantity of millet flour to absorb it all, and forming into small balls, which, when wanted, were broken, infused in boiling water, and the whole then mixed with the dough. A similar ferment may be prepared in this country from a decoction of raisins, which must subsequently be either pressed between boards with a heavy weight, or be mixed up with ground millet, as otherwise the strongest part of the must would remain amongst them. In summer, the leaven, yeast, and even dough, is apt to turn sour, and to communicate that taste to the bread; this is remedied by stirring a few tea-spoons-full of carbonate of magnesia into the ferment or dough.

Wheaten Bread.—The nature of wheaten bread when raised with yeast has been explained already at the commencement of this article; but the importance of the subject demands a more exact account of the established processes employed in the manufacture. Mr. Edlin wishing to obtain every information on this subject, procured access to a bakehouse, and has given us the following account. "At three o'clock, they prepared to set the sponge, for which purpose two sacks of household flour were carefully sifted through a brass wire sieve. The following mixture was then prepared; two ounces of alum was first put into a tin vessel with a little water, and dissolved over the fire; this was poured into the seasoning tub, and nine pounds of salt were thrown in, over which they poured two pails full of hot liquor; when cooled to 84° of Fahrenheit, six pints of yeast were added; this composition was then stirred well together, strained through the seasoning sieve, and emptied in a hole made in the flour, with which it was mixed to the consistency of thick batter. Some flour was sprinkled over the top, when it was covered up to keep in the heat. This operation is called *setting quarter sponge.* In three hours two pails full more of warm liquor were stirred in, and the mass covered up as before; this is termed *setting half sponge*. Five hours afterwards five more pails of warm liquor were added; and when the whole was intimately blended, it was kneaded for upwards of an hour. The dough was then cut into pieces, and thrown over the sluice board and penned to one side of the trough; some dry flour being sprinkled over, it was left to prove, till about three o'clock in the morning, when it was again kneaded for the space of half an hour. The dough was taken out of the trough, put on the lid, and cut into pieces. It was then weighed, and 4 lbs. 15 oz. was allowed for each quartern loaf, the baker observing that a loaf of that size loses from 10½ to 11 ounces while in the oven. It was then worked up, and the separate masses were laid in a row till the whole were weighed, and in counting them afterwards, he found they were equal to 163½ quartern loaves; but this circumstance is variable, as some flours kneaded better than others. It should have been mentioned, that the fire was kindled at two o'clock, and continued burning till near four, when the oven was

cleansed from dirt and ashes. The bread being put in, the oven was close stopped till seven o'clock, when it was opened, and the bread withdrawn."

Rolls.—Mr. Edlin has likewise furnished the following mode of making rolls, as witnessed by him in a London bakehouse. "The flour was sifted and mixed in the same manner as was done for the bread; at half-past six o'clock, they were moulded up, and a slit was cut along the top of each with a knife; they were then set in rows on a tin, and placed in a proving oven to rise till a quarter of an hour before eight, when they were drawn and set in the oven which was closed as before; at eight o'clock they were taken out, and were slightly brushed over with a buttered brush, which gave the top crust a shining appearance; they were then covered up with a flannel till wanted for sale."

Brown Bread, called also home-made, is usually fabricated of inferior or coarse flour, including more or less of the bran ground over again into pollard; and the brown tint of the latter is usually heightened by the public bakers, by the addition of the raspings of the burnt crust from other loaves. It has been a fashion of late years to give the preference to this bread, under the notion of its superior purity and wholesomeness, overlooking the obvious circumstance, that its dingy colour affords a protection to the discovery of all sorts of adventitious mixtures, besides that of dirty raspings. In making brown bread at home, the case is of course different; but here, owing to the deficient kneading it usually receives, it acquires an anomalous taste, which some call sweet, others sour. Being unsatisfactory to the appetite, the good lady in the country flatters her self-love in observing the increased appetite of her metropolitan visitors, and ascribes it to the excellence of her home-made bread, when, in fact, it arises from its imperfections. Brown bread retains more water after baking; hence it keeps moist longer, but the middle usually crumbles away.

French Rolls, &c.—That extremely delicate and vesicular small bread called French is made in the following manner. To a peck of flour sifted through a fine wire sieve, three quarters of a pound of butter are added, and rubbed together in a kneading trough; when these are intimately blended, two quarts of warm milk, a quarter of a pound of salt and a pint of yeast are well mixed with it, and a sufficient quantity of warm water to knead it into a dough; it must then stand two hours to prove, when it may be moulded into rolls or bricks, which are to be placed in tins, and set for an hour in the prover. They are afterwards put into a brick oven for twenty minutes, and when drawn rasped.

Household Bread undergoes the same preparation as wheaten bread, with this difference, that instead of being made with fine flour, it is made of an inferior sort, called seconds flour.

Substitutes for Wheaten Bread.—Numerous attempts have been made to find a substitute for wheaten bread, that should wholly or partially supply its place in times of scarcity. With this view, the annexed table has been prepared, by which will be seen the proportion of farina and of bran the following vegetable substances contain.

Kind of Grain.	a Bushel of, weighs	Weight of Flour in a bushel.		Weight of Bran in a bushel.	
Barley	46lb	38lb	10½oz.	5lb	10¼oz.
Buck Wheat	46¼	38	9	5	5
Rye	54	43	0	9	5½
Maize	53	44	0	8	10¼
Rice	61¼	60	0		
Oats	38¼	23	5	13	10½
Beans	57¼	43	5½	12	0
Peas	61¾	47	0	12	5
Potatoes	58	8	0		

We shall now proceed to shew how these several vegetable substances may be employed as substitutes for wheaten flour.

Barley Bread.—Next to wheat, barley is the most profitable of the farinaceous grains, and when mixed with a small proportion of that flour, makes a much

cheaper, and as good bread as that grain, as respects its nutritious properties; which is attested by the numerous robust peasantry who make it their chief sustenance. Barley is, however, made into bread without the admixture of any other grain, and forms the principal diet of the miners of Cornwall, and of the rural population of many districts in this country. It is thus made: forty-four pounds of barley meal are kneaded up into dough, with water, yeast, and salt, and divided into eight loaves; when thoroughly baked, drawn out of the oven, and left to cool, they weigh about 60 pounds. Such food must, however, be heavy; and to remedy this defect, it is always best to set the sponge with wheat flour altogether, as barley flour does not readily ferment with yeast; and add the barley flour when the yeast is going to be made. Barley bread is also made by a mixture of one peck of rice to two pecks of the barley flour: also, by the addition of 14 pounds of the drained pulp of potatoes, to the same weight of barley flour; knead into dough with warm water and a sufficient quantity of yeast and salt, and give the mass time to prove before baking.

Buck-wheat Bread.—Buck-wheat is so little used as an aliment in this country, that there is little opportunity of studying its effects; but from all appearance, it has the common quality of other grain. In Norfolk it is grown for fattening poultry. In France, it is made into bread for human sustenance. This grain is covered with a hard, black, triangular husk, of which it is deprived by an operation, previous to grinding the farina. It is effected by high drying the grain either by the sun's rays, or by the heat of a kiln, and afterwards by being what is technically called *run through* the mill stones; the husks are then blown away by a winnowing machine, and the residual grain treated as in the preparation of wheat corn. The manner of making bread from it alone is as follows: boil a gallon of water, add thereto by degrees a peck of buck-wheat flour, constantly stirring it, to prevent lumps forming, till a thick batter is formed like that of Scotch or Yorkshire pottage. Add some salt, and boil the mass for an hour and a half. Then pour into an iron kettle, hanging over the fire, the due proportion for a cake, and bake it, turning it frequently to prevent burning. An excellent mixed bread is made by the addition of a peck of wheat flour to the before-mentioned quantity of buck-wheat. After the latter has been made into batter, and cooled down to blood-heat, it may be poured into the trough containing the wheat flour and yeast; being there well kneaded, it should stand two hours to prove, divided into loaves, and baked rather longer in the oven than for wheat bread alone.

Rye Bread.—Bread from rye alone is not, we believe, eaten in this country, though in many parts of the north of Europe it is the ordinary diet of the people; a mixture of rye and wheat, however, forms excellent bread, and is very sweet and nutritious. To make the bread, knead together equal parts of wheat and rye flour, with a sufficient quantity of yeast, salt, and warm water; it should be covered up warm to ferment and prove, divided into loaves, and baked in the usual way. A mixture of rice with rye makes good bread, in the proportion of 15 pounds of rice to 60 pounds of rye. It is to be fermented with yeast, &c. kneaded, formed into loaves, and baked in the usual way: the product will be at the least 120 lbs. of bread.

Maize, or Indian Corn Bread.—Some authorities inform us that one half maize, and one-half barley, with a leaven of wheat flour, of one-fifth of the total weight, form a bread that is extensively eaten in the United States of America and in many parts of Europe; but that a superior bread is made with an equal quantity of wheat flour and maize. The late Mr. William Cobbett (to whom this country is indebted for the successful culture of a species of Indian corn,) directs the bread to be made of only one-third maize to two-thirds of wheat or rye flour. "Set your sponge," he says, "with the wheat flour only. As soon as you have done that, put the water (warm in cold weather and cold in hot weather) to the corn flour, and mix the flour up with the water, and there let it be for the present. When the wheat sponge has risen, and has fallen again, take the wetted-up corn flour and work it in with the wheat sponge, and with the dry wheat flour that has been round the sponge. Let the whole

remain fermenting together for about half an hour, and then make up the loaves, and put them in the oven."

Rice Bread.—Boil a small quantity of rice in water until it becomes very thick and glutinous; with this solution knead up the rice flour in the trough, to which is to be added sufficient yeast and salt. The dough being then covered warm with cloths, is suffered to stand till it rises. During the fermentation, this paste, which, when kneaded, was quite firm, becomes so soft and liquid as to render it necessary to be put in some shallow vessel, like a stew-pan, having a long handle, by which it is to be turned over in the oven, having first covered the rice paste with a sheet of paper; the heat of the oven operates so quickly upon the paste, as to cause it to retain the form of the vessel whence it was discharged. In this manner pure rice bread may be made; it is of a fine yellow colour, and of an agreeable taste. Its nutritive properties are sufficiently attested by the well-known fact that whole nations live entirely upon it. Rice, with a great variety of mixtures, produces excellent bread. The following combinations have been successfully employed: First, to half a peck of rice flour add one peck of wheat seconds flour; mix with yeast, salt, &c.; knead, ferment, and bake in the usual way. Second, to a peck of rice, boiled over-night till soft, and which in the morning will be found considerably swelled, add a peck of potatoes well mashed into a fine pulp, and a peck of wheat flour; a sufficient quantity of yeast and salt being added, and the whole kneaded, it may be left two hours to prove, before making up into loaves and baking.

Oat Bread.—Take a peck of oatmeal and an ounce of salt; stir them up into a stiff paste with warm water; roll it out into thin cakes, and bake in an oven, or over the embers. The Scotch peasantry live chiefly on this bread, though in some cottages they cause it to undergo a fermentation by sour leaven, which renders it more spongy and easy of digestion. Dr. R. Pierson has recommended the following as a good and economical bread: To a peck of oatmeal add the same quantity of seconds flour, and half a peck of potatoes skinned and mashed; knead up into a dough with yeast, salt, and warm milk; make up into loaves, and bake in the usual way. Equal quantities of oatmeal and rice flour made up the same as the foregoing in other respects, is stated to be very palatable, and must of course be very wholesome.

Bean Bread.—Bean flour does not essentially differ from other farina, but it has an unpleasant taste; this is, however, scarcely perceptible if the flour be steeped in water before it is used for making into bread. This flour, so treated, made up into cakes or bread with yeast and salt, is tolerable; but a good bread with a mixture of wheat and bean flour is thus made: Soak the flour for three days in water before it is required, changing the water every day, to carry off the peculiar flavour of the bean; then put the flour to drain over a sieve; during this operation put a peck of wheat flour into the kneading trough, and mix it up with yeast and salt. After it has been properly fermented, knead the bean flour with it into dough, and after it has stood a sufficient time to prove, divide it into loaves, and bake.

Pea Bread may be made in the same manner as directed in the foregoing article for beans; it is sometimes mixed up with oatmeal and made into cakes; but equal quantities of pea flour (that has been steeped), potatoe flour, and seconds wheat flour, afford a good bread. The sponge should be set with the wheat flour, and after fermentation the other flours kneaded in, allowed time to prove, then divided and baked.

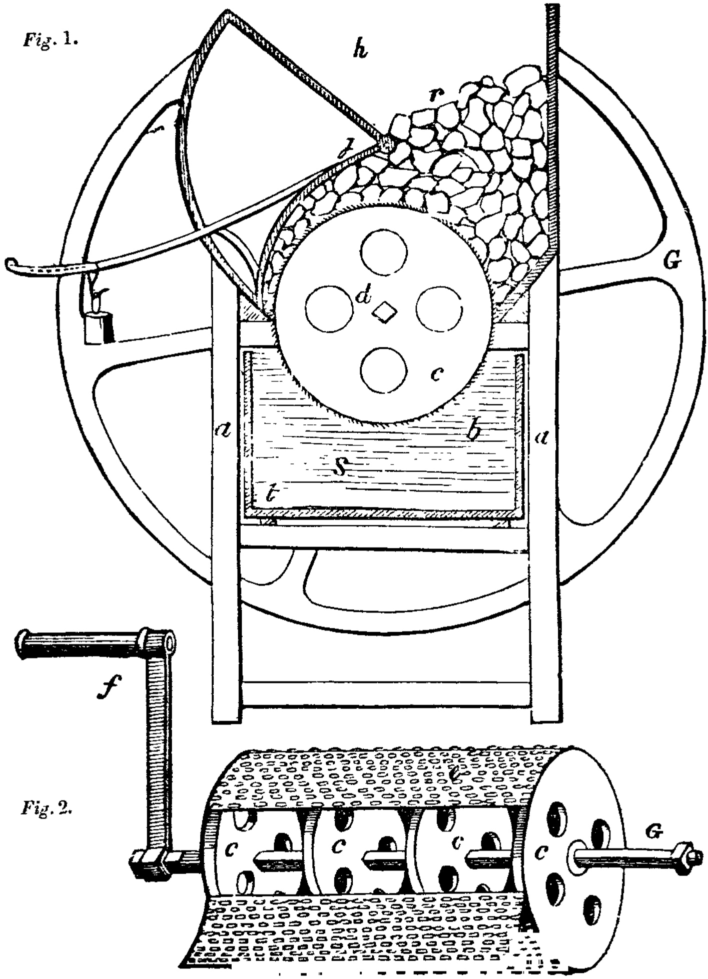
Potatoe Bread.—Pare the potatoes, boil them well, beat them to a pulp, and knead with double their weight of wheat flour, adding a sufficient quantity of yeast and salt; ferment, make up, and bake. The introduction of potatoes in moderate quantity into the best wheaten bread is by no means prejudicial to its quality. We believe that most persons find such bread, when well made, more palatable than that which contains none. It is not quite so dry, when new, as wheat flour alone; it retains its moisture much longer, and will keep for ten days without any trace of sourness. The following is the process employed by most bakers for introducing them: A cask is prepared by boring holes in its bottom; and the bottom made to fit into the mouth of a boiler containing water

If the quantity of flour to be baked be four cwt., the quantity of potatoes that can be properly used is five stone. The potatoes are thrown into the cask, a cover is applied, the water is made to boil, and the steam ascending through the holes of the cask boils the potatoes. The boiling is continued until the potatoes crack and become mealy. They are then withdrawn, and are pounded with a wooden instrument until they become quite fine. While this potatoe-meal is still very hot, cold water is added in such quantity as to reduce the whole to the thickness of butter milk. To this liquid, still warm, a gallon of yeast is to be added. A fermentation commences; and after it has continued sufficiently long, during which the potatoe-meal rises to the top and forms a tough mass, the whole is to be well mixed; and being now a homogeneous liquid, it is to be strained, first through a coarse hair sieve, and afterwards through a finer. To this strained matter, one half of the whole quantity of flour is to be added, and well worked up with the hands so as to form sponge. When the sponge has duly fermented, the other half of the flour is to be added, along with some more water holding salt dissolved: this mixture is to be worked up into dough, and treated in the usual manner. An extremely light and beautiful bread is made by the introduction of the pure starch of the potatoe, in various proportions (to the extent of one fifth part), to wheaten flour. The best mode of separating this starch from the root with which we are acquainted, is by the employment of a simple machine that we contrived for the purpose many years ago, engravings of which are given in the next page. *Fig.* 1 represents a vertical section of the machine. *Fig.* 2 is a perspective view of the grinding cylinder, with a part of the perforated covering turned back, to show the internal construction; *a a* is a strong square frame or stand, made of wood; *b*, a square cistern containing water, under which the grinding cylinder *c* is partly immersed; this cylinder, shewn separately in *Fig.* 2, is 11 inches in diameter, and 24 inches long; it is covered with a sheet of iron *e*, perforated throughout with small holes, produced by means of a steel punch, having a quadrangular pyramidical point, which raises four distinct burs or teeth, particularly adapted to the purpose of rasping; this perforated plate is nailed to the peripheries of four turned discs of wood, which thus produce the cylindrical figure, and each disc has a series of large holes *d* made through it, for the free passage of the water throughout the cylinder. The axis is mounted in plummer blocks, fixed on the frame, (not seen in the drawing,) and is turned by a winch handle *f*, or any other convenient means. G is a fly wheel, to equalise the motion. The potatoes are put into a hopper *h*, the lower extremity of which is formed into a square frame which encompasses the upper half of the cylinder in an exact manner, but not so as to touch it, in order that it may turn round freely. The hopper is also provided with a movable curved portion *i*, turning upon a joint, and serves to press the potatoes *r* against the cylinder, as the latter is turned round by the agency of a lever *k*, on which a weight is suspended,—a traversing weight to vary the pressure. The curved side of the hopper is made of sheet iron, and has a long slit in the middle to allow the lever *k* to traverse, and as a guide to it. In setting this machine to work, the hopper is to be filled with potatoes washed perfectly clean, and the cistern is to be about two thirds filled with water, or so that the cylinder dips two or three inches into it. The weight being then applied to the lever *k*, the operation of grinding is commenced, and continued until the cistern is nearly filled with the pulp; but before this takes place, the water in the cistern rises so much that a portion of it must be run off, or ladled out into another vessel, as the water which is not then clear contains a portion of the finest starch, that takes an hour or more to subside. The grinding of a bushel of potatoes into pulp by a machine of this size takes a man about a quarter of an hour, from which fact it will be seen, that one horse power is adequate to the reduction of about 24 bushels per hour. The next process to grinding down is the separation of the starch from the fibre, and other extraneous parts. For this purpose, the cistern, which is upon rollers, is drawn forward out of its situation about 6 inches, which allows sufficient room for the pulp being emptied out by means of a bowl into a sieve; or instead of the latter, into a piece of lawn

stretched over a tall tub, (the best form of which is, that of the inverted frustrum of a cone;) the lawn being tied down by a cord passing round beneath a hoop on the top of the tub. The operation is thus performed; a bowlful of the pulp is first thrown on the strainer, (which is rendered concave by the pressure,) and immediately another bowlful of clear water, from a reservoir at hand, is dashed down upon the former; the dilution which it thus receives causes the starch to pass rapidly through the strainer, this effect being increased

Fig. 1.

Fig. 2.



by the operator continually stirring up the mixture with his left hand. A small portion of starch remains after the first affusion, but which is entirely removed by a second dose; the fibrous remains are then cleared off the strainer, and a fresh portion of the pulp from the cistern is thrown on the filter, and treated as the former, and the operation thus continued until the cistern is emptied. The cistern is again filled with water as before, the hopper replenished with potatoes, and thus the grinding and washing away of the starch is alternately performed: this variation in the process affording the man an

agreeable change from the labour of turning the mill. It is advisable to use two tall tubs like that already described, and to employ them alternately; which will afford sufficient time for the starch to settle at the bottom of each in a solid cake, while the process is being continued with the other tub. About four inches above the bottom of each tub there should be a stop-cock to draw off the supernatant liquid, which is of a reddish brown colour. The starch should next be removed from the bottoms of the tubs, (as it is inclined in warm weather to undergo very soon the acetous fermentation, whilst wet, with the coloured water deposited between its particles,) and placed in large glazed pans, wherein it should be washed or stirred up again with fresh water, and allowed to settle again in solid cakes; and this operation should be repeated until the water runs off colourless, which will usually be at the third or fourth time of drawing off. The starch then settles quickly into a firm and beautifully white cake. It has next to be dried, which is preferably done in the open air, or exposed to the rays of the sun, in a situation free from dust. The mass should be made into lumps with the fingers, and spread out on rectangular frames of wood, over which is stretched any cheap cloth: these, from their form, are very portable, and stand well upon one another, like the frames used by glue boilers for drying their manufacture. When thoroughly dry, it may be stowed away into casks; and if kept unexposed to damp, may be preserved good for a century. In constructing an apparatus for conducting this manufacture on a large scale, many improvements on the foregoing might be made to expedite the work and facilitate the labour, which are too obvious to need our entering further into the subject. It is, however, due to Mr. Whately, of Cork, to observe that that gentleman had invented a machine very similar to the foregoing, some time previous to its publication, but unknown to the author. The difference between the two machines is quite immaterial, excepting that in Mr. Whately's the grinding cylinder works *out* of water, which renders it liable to clog up,—an effect which is prevented by the arrangement of the other. In a communication made by Mr. Whately to the Society of Arts, (who presented him with their honorary gold medal for the invention,) he states, that "it is capable of the most satisfactory proof that the same quantity of land will yield above one-half more of farina, or flour, where potatoes are cultivated, than if the same quantity of land was applied to the production of wheat." He further states, "I have proved from experiment, that 2,619 lbs. of pure farina, or flour, may be produced from an acre of land planted with potatoes, and only 1,600 lbs. of flour from an acre of wheat. It will therefore be obvious, that if we can apply this great excess to the same purposes as the flour of wheat, the advantages arising from it will be of the greatest importance to the community." It is, besides, well known that many poor light soils, which are considered unfit for the cultivation of wheat, will produce good potatoes abundantly. The cost of producing potatoe flour from the root, Mr. Whately estimates at only half that of obtaining the flour from the wheat. In the introduction of a small portion of potatoe flour in the manufacture of sea-biscuit, it is said the quality is materially improved, and that they will keep good for a much longer period of time; and it may be fairly urged, that if potatoes in the gross improve (as it is generally admitted they do) the quality of wheat bread, that they must be still more beneficial when deprived of the refuse matter they contain. This article is, nevertheless, considered legally as an adulteration of bread, as well as many others, some of which we shall proceed to notice. The most common sophistication in bread is alum. Some writers state that as much as 4 oz. are put into every quartern loaf by the public bakers; but bread containing so large a quantity could not be eaten without serious constipation. From the best information afforded to us, we are inclined to believe the quantity of alum varies with the quality of the flour, the worst flour receiving the most alum to improve the colour; and that the quantity put to a sack of flour (though it varies from 4 oz. to 4 lbs.) is usually about 2 lbs.; and as this will assign to each 4 lb. loaf nearly ¼ oz., it is very probable the before-mentioned statement of 4 oz. to each loaf arose from an uncorrected error of the press. It has been asserted that bones burned to whiteness, and ground to an impalpable powder,

are used to adulterate *thirds* flour; this we trust, however, is a very rare occurrence. Chalk and whiting, in small quantity, are also, it is said, sometimes mixed with flour. Salt, although a necessary ingredient in bread, is sometimes added to such an excess that it becomes an adulteration; the object attained by it is the causing the bread to retain a portion of the water which, without it, would be evaporated in the process of baking. If bread contain an unusual proportion of starch, it absorbs and retains more water from that cause. Such bread, therefore, is deficient in solid matter, and is technically termed *hungry* bread, as an equal bulk and weight does not satisfy the appetite like bread which holds less water. The bakers prefer flour that has been made about three months, or such a mixture of old and new flour as will make an equivalent. Weak inferior flour requires the dough to be made up as dry as possible. If the usual quantity of water required for the best flour be used, there is a liability to the fermentation running into the acetous stage, which of course renders the bread sour. In all cases, if the dough has been made too soft, it should be cooler than usual, otherwise the high heat of the over quickly forms a crust imperviable to vapour, and thus locks up the water in the bread. Bread in this state is very common amongst the home-made, for want of due experience in the operator. In the employment of flour made from wheat that has undergone germination, it becomes necessary to have recourse to some extraordinary means to render the bread light. Mr. E. Davy, who made many experiments with a view to determine the best remedy for such malted flour, ascertained that the carbonate of magnesia of the shops, when well mixed with the new flour, in the proportion of from 20 to 40 grains to 1 lb. of flour, materially improves it for the purpose of making bread. Loaves made with it rise well in the oven; they are light and spongy, and keep well. To the worst flour as much as 40 grains may be added to 1 lb. of flour. Care should be taken to mix them intimately together. When too little yeast has been added to the dough, the fermentation is slow and incomplete; when it has been added in too great a quantity, the fermentation becomes too rapid, and renders it liable to sourness; to remedy which, Mr. Chaptel has recommended the kneading up some carbonate of potash with the dough, which neutralizes the excess of acid. Dividing the dough into small masses, and exposing it to the air, also has a tendency to check the fermentation. Under the several heads of CORN, DOUGH, MILL, OVEN, &c. a variety of improvements in the mechanism and processes of making bread will be found.

BREAKWATER. An artificial wall or rampart carried nearly across the mouth of an open harbour or bay, to protect vessels moored behind it from the violence of the sea. The two most celebrated structures of this kind are those of Cherbourg and Plymouth. The breakwater at Cherbourg was commenced about the year 1783: it was to consist of a series of truncated cones of timber, approximating at their bases, and presenting to the sea, as they rose to its surface, alternate obstacles and openings. The number of cones, as originally projected to cover a front of 2,000 toises, was ninety, which were afterwards reduced to sixty-four; but this number was never completed. Each cone was to be 150 feet in diameter at the base, and 60 feet at the top, and from 60 to 70 feet in height, the depth of water at spring tides, in the line in which they were to be sunk, varying from about 56 to 70 feet. The cones were to be formed without bottoms, and being floated off by means of casks attached to them, were to be towed to the spots whereon they were to be sunk; they were then to be filled with stones to the tops, and left to settle for a while; after which the upper part, commencing at low-water mark, was to be built with masonry laid in pozzolana, and encased with granite stone. The first cone was sunk June 1784, and by the year 1788 eighteen cones had been sunk, occupying a line of 1,950 toises in length; but owing to the disasters which had attended the progress of the works, (the upper parts of several of the cones having been carried away by the violent winter gales,) the undertaking was suspended; in the following year three cones, then building, were sold by auction. Subsequently a plan for casing over the whole length of the old work with blocks of stone was so far acted upon, that in 1803 the centre of the dyke had been brought above high-water mark, and here were placed a battery and a small

garrison, the whole of which were swept away by the sea in a heavy gale of wind in 1809. Small spots only of the breakwater are now visible above the surface of the sea at low-water spring tides, except near the middle, where a shapeless mass (extending about 100 yards in length) rises to the height of from 18 to 24 feet above high water. Plymouth Sound is very much exposed; and the heavy swell constantly rolling in is much increased when the wind blows fresh from any point between S.E. and S.W. In the year 1806 the improvement of the anchorage in Plymouth Sound, by the erection of a breakwater, was suggested by the late Earl St. Vincent to Earl Grey, then first lord of the Admiralty; and in the same year Messrs. Rennie and Whidbey were directed to report on the practicability of the plan. Their report was favourable; but from various causes the work was not decided upon until 1811. The method which was recommended for constructing the work was to sink very large blocks of stone in the line of the intended breakwater, allowing them to find their own base, and to assume those positions which gravity would permit, and that blocks of stone from 1½ to 2 tons weight would be sufficiently heavy to resist the action of a stormy sea. The immense beds of limestone east of Catwater, which were capable of affording stones of still larger dimensions, were bought by government for the sum of 10,000*l*., and were opened on the 7th of August, 1812, under the superintendence of Mr. Whidbey: five days after the first stone was deposited in the Sound, and on the 31st March, 1813, the breakwater was first seen above the surface of the sea at low water. The breakwater consists of a central part of 1,000 yards in length, and of two wings, each of 350 yards, forming, with the middle portion, angles of 158°, the angular points being turned towards the ocean. The transverse section is of the form of a trapezoid, whose base on an average extends to about 290 feet; its breadth at top 48 feet; and its average depth about 56 feet. The rise of the slope facing the sea is 1 in 7; that of the slope facing the harbour 1 in 5. The average depth of water is 36 feet at low water spring tides, and the breakwater is carried about 20 feet higher, which somewhat exceeds the greatest rise of the tide. The whole length is now (1833) completed, and on the surface the blocks are formed into a convenient path from end to end; but it is decided to build or encase the upper part in solid masonry, commencing at low water mark, and to erect a lighthouse near the centre. The quantity of limestone required for its construction, was estimated by Messrs. Rennie and Whidbey at about 2,000,000 tons, and the probable expense 1,171,000*l*.

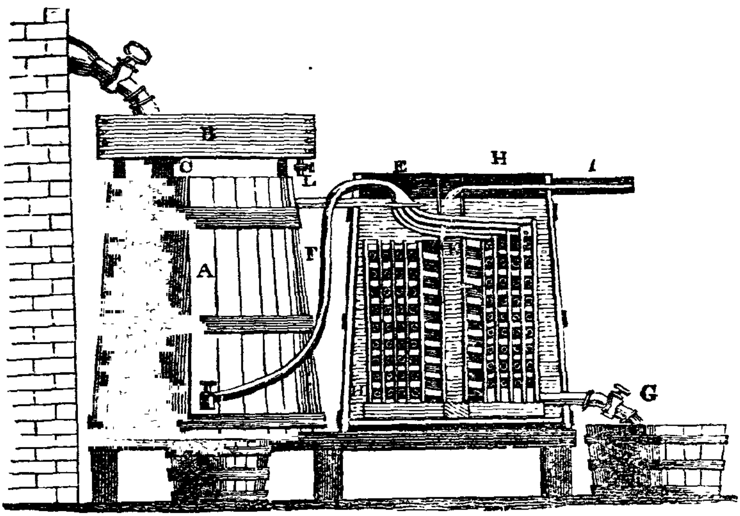
BREWING. The art of preparing ale or beer. The materials commonly used for this purpose are malted barley and hops. The ingredients serve as the basis of all ale and beer, and, indeed, are the only ones permitted by law; but most public brewers, in addition, make use of a variety of other articles to improve the appearance of the beer, or to suit the taste of their customers. Each brewer has his own recipes for these purposes, which he endeavours to keep secret; but many of the substances so employed are known to be of a very noxious nature. The brewing of beer of all kinds is conducted by the same general process; the principal variations in it depend upon the scale upon which the operation is carried on; we shall therefore first give an outline of the process as adapted to private families, and afterwards a description of the manner in which the operation is conducted in public breweries on a large scale. The method usually followed in brewing on a small scale is as follows: The malt coarsely ground, or rather crushed, is strewed evenly over the bottom of a broad tub, called the mash-tub, which is furnished with a wooden spigot or cock, near the bottom, over the inner end of which is fitted a strainer of basket-work to keep out the grains. A quantity of water, proportioned to the quantity of malt and the strength intended for the beer, is then boiled in a copper, and afterwards allowed to cool down to about 170° Fahr.; this is then poured gradually over the malt, which is stirred all the time with a sort of rake of a triangular form. When the whole of the water has been poured on the malt, the tub is covered with matting or sacking to retain the heat, and the malt is stirred from time to time. When the water has been two hours on the malt, it will have dissolved the greatest portion of the saccharine matter of the

grain; the solution is called *wort*, which is drawn off into a tub beneath the mash-tub, and another portion of water, less than the first, and at about 180° Fahr., is poured over the malt. After this has stood for about an hour, it is likewise drawn off, and may either be mixed with the former worts, or kept separate to form an inferior description of beer. A third water is sometimes given, which should be at 190° Fahr. When the whole of the saccharine matter is extracted from the malt, the remainder is called grains, and is used for feeding pigs. The worts are then removed to the copper, and either boiled with the hops, in the proportion of 1½ lb. of hops to a bushel of malt, or (which is a better way) an infusion of hops, previously prepared at a gentle heat, is added to the worts, and the whole is boiled rapidly until the liquor *parts*, as it is called, that is, the mucilaginous parts which were suspended in the liquor, and rendered it turbid, separate from it, appearing like a quantity of white worms swimming through the liquor, and if a small portion of it be taken in a glass, the liquor quickly becomes clear, and a thick sediment is precipitated. The liquor is then poured through a coarse strainer (to separate the hops) into shallow tubs, placed, if possible, where there is a current of air, in order to cool as rapidly as possible; and when it has come down to about 60° Fahr. it is collected into the fermenting tun, and the yeast (first mixed with a small quantity of worts) is added to the liquor, and well incorporated with it by stirring it with a new birch broom; the tun is then covered up with cloths, and the temperature of the room maintained a little above 60°. In a short time fermentation commences, forming a white head on the surface of the worts, and a large portion of carbonic acid gas is evolved, accompanied by a strong vinous odour. As soon as the head begins to fall, the beer is removed into casks, with the bungs left out for the escape of the yeast, which comes over in considerable quantities; the casks being replenished at intervals to compensate for the portion of beer which is carried over with the yeast; and when the yeast ceases to come over, the casks are first lightly, and afterwards securely, bunged up for future consumption.

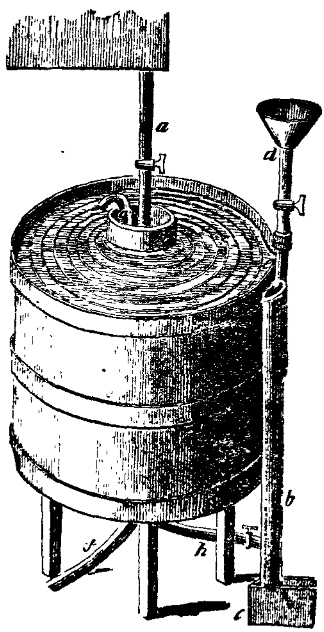
We shall now proceed to describe the process as usually conducted in a brewing establishment on a moderately large scale. The first operation is the proper grinding, or rather crushing of the malt; this is sometimes performed between mill-stones, in the manner in which corn is ground, only the stones are set rather further asunder; but of late years it has become more common to crush the malt between two cylinders. The malt is then suffered to lie some time in a bin or cool room, to mellow, as it is called. Grist thus exposed to the air it is said requires less mashing, and the strength of the malt is more perfectly obtained. Mashing in the large way is usually performed in a circular wooden or cast iron vessel, called the mash tun, and furnished with a false bottom perforated with holes. Between the real and false bottom, which are generally a few inches asunder, are two side openings; to one is fixed a pipe for conveying hot water into the tun, and to the other a pipe and cock for discharging the liquor into another vessel. The mashing is performed by machinery invented for that purpose. These machines are variously constructed; the following is one of the most approved description. In the centre of the tun is a vertical axis, which is turned round by wheel-work at the top. Upon this axis is a bevelled wheel, which turns a horizontal axis extending from the centre to the circumference of the tun. This axis has four wheels upon it, over which pass four endless chains, which also pass round wheels on a horizontal axis near the bottom of the tun. Upon the endless chains are fixed iron rakes, which, as the wheels revolve, bring up the malt from the bottom of the tun to the top. These also receive a slow progressive motion round the tun by the following means: the outer ends of these axes are supported in bearings in a vertical frame, which rises to the top of the mash tun, and is braced to a collar on the vertical shaft. On the top of this frame is a bearing, to support the outer extremity of a horizontal shaft, on the inner end of which shaft is a bevelled wheel, which works in another bevelled wheel on the vertical shaft. The horizontal shaft, by means of another bevelled wheel fixed at its outer extremity, gives motion to an endless screw, supported by a carriage attached

to the vertical frame, and the endless screw acting upon a ring of teeth fixed upon the curb of the mash tun, causes the mashing apparatus slowly to perform the circuit of the tun. After mashing, the tun is generally covered, to prevent the escape of heat, and the whole remains untouched until the insoluble parts separate from the liquor, when the wort is discharged into another vessel usually placed beneath the mash tun, and called the underback. To extract entirely the saccharine matter from the malt, a second, and sometimes a third, mashing is taken, and the whole extract is received into the underback, and thence conveyed to the copper. For heating the water and boiling the wort, large establishments use a copper crowned with a hemispherical dome, surrounded by a pan which will contain a succeeding wort. The liquor is generally boiled by steam in the following way: From the centre of the dome rises a perpendicular pipe, and from the upper extremity of this pipe four inclined pipes descend, the lower extremities of which terminate near the bottom of the pan, and consequently in the water or wort contained therein. By this contrivance the steam which rises from the copper must bubble up through the fluid in the pan, and speedily heat it. The advantages of this plan are, that the instant the copper is emptied, a fresh supply of liquor can be let in to cover it, in order to prevent the intense heat of the fire from injuring the bottom of the copper, while the successive fluids are heated by one fire. The copper is provided with two man-holes, fitted with lids which screw tight down. One of these is for the purpose of admitting a man to clean the copper, and by the other the hops are introduced; the general proportion is 1¼ lb. of hops to a bushel of malt. After the first boiling with hops the liquor is let off, and the wort is conveyed into the jack or hop-back, furnished generally with a cast iron floor full of holes, so as to drain the wort from the hops. Then those left in the hop-back are filled by men into tubs which are drawn up by a tackle worked by the engine, and again boiled in the copper with the second and third worts. From the hop-back the worts are next conveyed to the coolers. These usually consist of several floors or stages, erected in the most airy and exposed situation which the premises afford. They are surrounded by shallow ledges, and the worts are pumped on to these to the depth of a few inches, and by the aid of a current of air operating upon a very extended surface, they are in the course of seven or eight hours cooled down to about 60°, which is the average temperature for setting to work. There are several inconveniences attending this method of cooling: a considerable loss arises from evaporation; the process is tardy and uncertain, depending greatly upon the temperature of the atmosphere; and the erection of such extensive and lofty buildings as are necessary adds considerably to the expense of the *plant*. To obviate these evils, many persons have proposed to cool the worts by causing them to flow through thin metal pipes surrounded by cold water, and many arrangements for the purpose have been patented. The following one is the invention of Mr. Bundy. A is a tub filled with cold water, in which is fixed a series of metal pipes, capable of cooling a certain quantity of wort per hour, according to the size of the apparatus. The wort may be let to run either direct from the boiler into the hop-back, or (as convenience may permit) be ladled into B after straining from the hops. The wort then passes from B through the main conducting pipe C into the series of pipes, and is delivered out through the cock D into the gyle tun, adjusting the quantity by opening the cock more or less, by which means the heat of the wort may also be regulated, so that it may run out of the proper temperature to be immediately fermented. The other vessel H is a longitudinal section of a precisely similar vessel and apparatus as A, and consequently exhibits a section of all the series of pipes, their spiral winding and situation. Now if, instead of drawing the wort off at D, as before mentioned, that cock were kept shut, the wort would flow out of the first series of pipes contained in the vessel A, into the pipe F, and there ascending to its level, it would descend and be distributed through the second series of pipes at E, contained in vessel H, which being kept constantly filled with cold water, condenses the vapours, whilst it rapidly cools the liquid wort in its extended circuitous passage through the convoluted series of pipes, till it is discharged at the cock G, where it arrives

properly refrigerated, in more than double the quantity in a given time than would be delivered at D if the vessel A alone were used. A continual supply of cold water is indispensable, which may be pumped into the tub H by passing



along the shoot I, and descending by means of the trunk K to the bottom, which being left open, drives the water that has been made warm by the wort in the pipes, to the upper part of the vessel, from whence it flows by the shoot L into the trunk of the vessel A, which is similar to that in H. By these means the water which is driven off at the top of the tub A is much hotter, and, consequently, has deprived the wort passing through the pipes of much more heat than in the case of the single tub A being used. When the tub A is sufficient by itself for the purpose required, the cold water is then of course to be pumped into the shoot L.



An apparatus for the same purpose, invented by Mr. Wheeler, of High Wycombe, Bucks, is represented in the accompanying cut. A series of copper plates tinned are first soldered together lengthwise, and another similar series are connected with the former, by soldering their longitudinal edges together in such manner as to leave between them (except at the edges) a space of about a quarter of an inch; they are afterwards convoluted into the form shown in the engraving, and placed in a tub or cylindrical vessel; within the narrow and continuous chamber thus formed, the wort is made to flow from a copper or reservoir, while the water or other cooling fluid runs in a contrary direction, by which arrangement the two fluids will nearly exchange their temperatures, the water becoming heated and the wort cooled. *a* represents

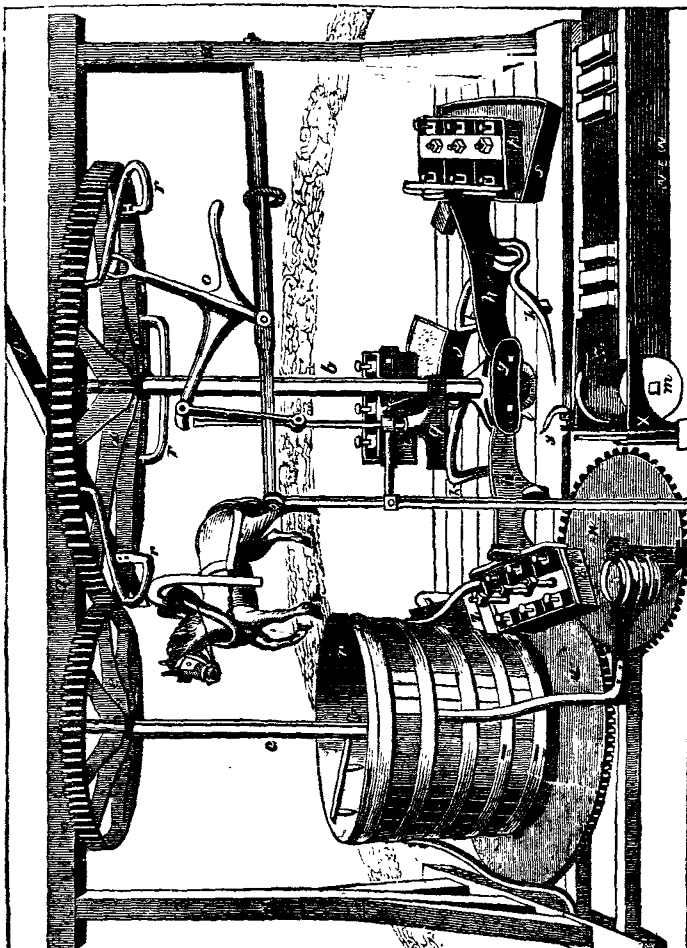
the service pipe and cock, which brings on the water from a cistern above; it enters at the bottom of the vessel, in the centre of the convolute, from thence passing round the coils it abstracts the heat from the wort contained in the flat chambers, and passes off in a heated state at the upper part of the pipe *b*, and descends into the trough *c*. The wort is received at *d*, the lower part of which pipe has an opening into the narrow convoluted chamber; the wort circulating through all these coils arrives at the centre, from whence it descends and passes out by a pipe *f* in a cool state. At *g* there is a small curved pipe, to allow the air in the wort chambers to escape; at *h* is a pipe and cock for discharging the water in the tub whenever needful. We are not aware of any brewing establishments having entirely dispensed with the cooling stages, but several combine with them the plan of cooling by water, by surrounding the pipe which conveys the worts to the fermenting vessels with another pipe of a few inches larger diameter, and maintaining a current of cold water through the same. From the coolers the worts pass to the large fermenting square, where the yeast is added, and where the first fermentation is carried on. When the violence of it begins to subside, the liquor is conveyed by a pipe to a series of circular or square vats, ranged in double rows in a large building, called the fermenting-house. In these vats (which are all of an equal height) the liquor purges itself, throwing up the yeast in large quantities, which, running over the tops of the vats, together with a portion of the beer, is conveyed by drains formed between every double row of vats, to cisterns formed to receive it. The beer which is thus carried over is replaced by a fresh quantity from a small reservoir on a level with the large fermenting square, and the liquor is maintained at the same level in all the fermenting vats by means of a ball cock. When the fermentation in the vats has ceased, the beer is in some establishments received into cisterns of wrought stone, built at some depth below the surface, in which the beer is left to mellow; in others it is pumped into immense vats, the heads of which are covered with sand to the depth of a foot, to preserve them air-tight.

BRICK. A kind of factitious stone, made of a fatty earth formed into a parallelogram about 4 inches broad by 8 or 9 inches in length, by a wooden mould, and then baked or burnt either in a kiln or a clamp, to serve the purposes of building. Bricks appear to have been used for architectural purposes at a very remote period, as we learn from the Scriptures that the Israelites were employed to make bricks in Egypt; and some of the most durable of the Greek and Roman monuments which have come down to us, are wholly, or in great part, constructed of this material. In the East they bake their bricks in the sun; the Romans used them crude, only leaving them a long time in the air to dry, about four or five years. In modern times, brickmaking is no where carried to greater perfection than in Holland, where most of the floors of the houses, and frequently the streets, are paved with excellent and very durable bricks. Loam and marl are in England considered the best materials for bricks. The former is a natural mixture of sand and clay, which may be converted at once into bricks; marl is a mixture of limestone and clay in various proportions. The neighbourhood of London is remarkably adapted for the making of bricks, the soil of the whole surrounding country being clay at a certain depth, generally below a bed of gravel, and the bottom of the Thames yielding the sand which is used in this manufacture; but great practical carelessness seems to pervade the whole business as conducted there. The following is a description of the process as it is usually conducted around the metropolis: The earth is dug up in the autumn, and suffered to remain in a heap until the next spring, that it may be well penetrated by the air, and particularly by the winter frosts, which, by pulverising the more tenacious particles, greatly assists the operations of mixing and tempering. In making up this heap for the season, the soil and ashes, or sand, are laid in alternate layers or strata, each stratum containing such a thickness as the stiffness of the soil may admit or require. In tempering the earth, much judgment is required as to the quantity of sand to be thrown into the mass, for too much renders the bricks heavy and brittle, and too little leaves them liable to shrink and crack in the burning. The addition of sea-coal ashes, as practised about London, not only makes it work easy, but saves

fuel, as when the mixture is afterwards sufficiently heated these bricks are chiefly burned by the fuel contained in the clay. When the brick-making season arrives, the heap is dug up, the stony particles carefully removed, and the mass properly tempered by a thorough incorporation and intermixture of the materials, with the addition of as little water as possible, so as to form a tough viscous paste. If, in this operation, too much water be used, the paste will become almost as dry and brittle as the soil of which it is composed. In order more effectually and regularly to mix the loam and ashes, it is now generally performed in a sort of mill, named a pug mill. This consists of a large tub or tun, fixed perpendicularly in the ground, and having an upright bar, fitted with knives, placed obliquely. The upright bar is turned by a horizontal lever, to which a horse is attached, and the soil being put in at top, is, by the revolution of the knives, forced through a hole in the side of the tub near the bottom, whence it is removed to the mould table, which is placed under a movable shed, and is strewed with dry sand. A girl rolls out a lump somewhat larger than the mould will contain. The moulder receives this lump from the girl, throws it into his mould previously dipped in dry sand, and with a flat smooth stick about 8 inches long, kept for the purpose in a pan of water, he strikes off the overplus of the soil; he then turns the brick out of the mould upon a thin board rather larger than the brick, upon which it is removed by a boy, who places it on a light barrow of a particular construction, which being loaded with a certain number of bricks, they are sprinkled with sand, and wheeled to the hacks. The hacks for drying are each wide enough for two bricks to be placed edgeways across, with a passage between the heads for the admission of the air, to facilitate the circulation of which the bricks are usually laid in an angular direction. The hacks are usually carried eight bricks high; the bottom bricks at the ends are usually old ones. In showery weather the hacks must be carefully covered with wheat or rye straw, unless sheds or roofs be built over the hacks, as is done in some parts of the country, but in London this is impracticable, from the very great extent of the grounds. In fine weather the bricks will be ready for turning in a few days, in doing which they are reset more open than at first, and in six or eight days more they will be ready for burning. In the vicinity of London bricks are commonly burned in clamps. In building the clamps, the bricks are laid after the manner of arches in the kilns, with a vacancy between every two bricks for the fire to play through. The flue is about the width of a brick, carried straight up on both sides for about three feet; it is then nearly filled with dry bavins or wood, on which is laid a covering of sea coal and cinders (or, as they are termed, *breeze*); the arch is then overspanned, and layers of breeze are strewed over the clamp, as well as between the rows of bricks. When the clamp is about six feet wide, another flue is made in every respect similar to the first. This is repeated at every distance of six feet throughout the clamp, which, when completed, is surrounded with old bricks, if there be any on the grounds, if not, with some of the driest of the unbaked ones reserved for the purpose; on the top of all, a thick layer of breeze is laid. The wood is then kindled, which sets fire to the coal; and when all is consumed, which will be in about twenty or thirty days if the weather be tolerable, the bricks are concluded to be sufficiently burned. To prevent the fire burning too furiously, the mouths of the flues are stopped with old bricks, and the outside of the whole clamp plastered with clay; and against any side particularly exposed to the rain, &c. screens are laid, made of reeds worked into frames about six feet high, and of a width to admit of being moved about with ease. This is the mode of manufacturing the ordinary descriptions of bricks; but the superior sort, termed *washed malms* or *marls*, are tempered with greater care and attention. For this purpose a circular recess is built about four feet high, and from ten to twelve feet diameter, paved at bottom, with a horse wheel placed in its centre, from which a beam extends to the outside for the horse to turn it by. The earth is then raised to a level with the top of the recess, and forms a platform for the horse to walk upon. Contiguous to the recess a well is formed for supplying the recess with water, which is raised by a pump worked by the horse wheel. A harrow made to fit

the interior of the recess, thick set with long iron teeth, and well loaded, is chained to the beam of the wheel to which the horse is harnessed. The soil prepared in the heap in the usual manner is brought in barrows, and distributed regularly round the recess, and a quantity of chalk is added, and a certain portion of water; and the horse being set in motion, drags the harrow, which forces its way into the soil, admits the water into it, and by tearing and separating the particles, not only mixes the ingredients, but also affords an opportunity for stones and other heavy matters to fall to the bottom. Fresh clay, chalk, and water, continue to be added until the recess is full. On one side of the recess, and as near it as possible, several hollow square pits are prepared about 18 inches or 2 feet deep. The soil, reduced to a kind of liquid paste, is discharged from the recess by a sluice, and conveyed by wooden troughs to this pit. In these pits the fluid soil diffuses itself, settling of an equal thickness, and remains until wanted for use, the superfluous moisture being drained or evaporated away by exposure to the atmosphere. The remainder of the process is the same as for the common sort of bricks. In the country, bricks are always burned in kilns, whereby much waste is prevented, less fuel is consumed, and the bricks are more expeditiously burned. A kiln is usually 13 feet long by 10 feet 6 inches wide, about 12 feet in height, and will burn 20,000 bricks at a time. The walls are about 14 inches square, and incline inwards towards the top. The bricks are set on flat arches, having holes left between them resembling lattice work. The bricks being set in the kiln, and covered with pieces of broken bricks or tiles, some wood is put in and kindled to dry them gradually; this is continued till the bricks are pretty dry, which is known by the smoke turning from a darkish to a transparent colour. The burning then takes place, and is effected by putting in brush-wood, furze, heath, faggots, &c.; but before these are put in, the mouths of the kiln are stopped with pieces of brick called *shinlog*, piled one upon another, and closed over with wet brick earth. This shinlog is carried just high enough to leave room sufficient to thrust in a faggot at a time; the fire is then made up, and continued till the arches assume a whitish appearance, and the flames appear through the top of the kiln, upon which the fire is slackened, and the kiln cooled by degrees. This process is continued, alternately heating and slackening, till the bricks are thoroughly burned, which is usually in the space of forty-eight hours. Many attempts have been made of late years to supersede, by the aid of machinery, a portion of the manual labour now employed in the manufacture of bricks; and although only the most recent of the machines invented for this purpose have been found to answer in practice, several of them are worthy of notice. The engraving on the following page represents Messrs. Choice and Gibson's brickmaking machine. *a a a a* is an upright frame, with cross beams at top and bottom; *b c* are two vertical shafts, carrying two horizontal spur wheels *d* and *e*, the teeth of which take into one another; these are put in motion by the horse shaft *f*, or any other convenient power. Near the bottom of the shaft *b* is fixed a large cast iron collar *g*, having three deep mortices; into each of these the end of an iron arm *h* is fitted, with a bolt passing through them to form a centre, as in a hinge joint. To the other extremity of each of the arms *h* is firmly fixed, by screw-bolts, a cast-iron mould box *i*, having three divisions for three bricks, in which work three stocks or false bottoms, having upright bolts passing through holes in the top. By the revolution of the shaft, these mould boxes, with their arms, are successively carried up and over the risers *k k k*, which form circular curves in the plan, and appear so in the perspective, but are in reality inclined planes. At *l*, near the bottom of the shaft, is a small bevelled wheel, which actuates a pinion fixed on the spindle of the drum wheel *m* that passes under the floor of the machine; an endless strap passing round the drum *m*, and another placed at the required distance, continually carries the bricks forward to their destination as fast as they are made, and deposited upon it. *o* is a crank or lever, attached by a joint to the framing, as shown, at the upper end of which is fixed a roller; by the revolution of the wheel above the three circular bars or cams *r r r*, attached to the wheel, successively act upon the roller, and depress the crank *o*, which first raises the rod and weight *q*, and afterwards, as soon as the crank is relieved

of the pressure, allows it to drop and strike the mould boxes, by which the bricks are discharged out of them. *s* is a box of cast iron, containing water, into which the mould boxes dip; *t* is a cushion, upon which they next fall in succession, by which the superfluous water is taken off; and *j* is a box of dry sand, into which the mould boxes afterwards fall, their surfaces becoming in consequence slightly coated with sand previous to becoming charged with clay. The horizontal wheel *e* worked by *d* actuates the shaft *c* bearing the knives in the pug mill. At the lower end of the shaft *c* is fixed the large circular revolving

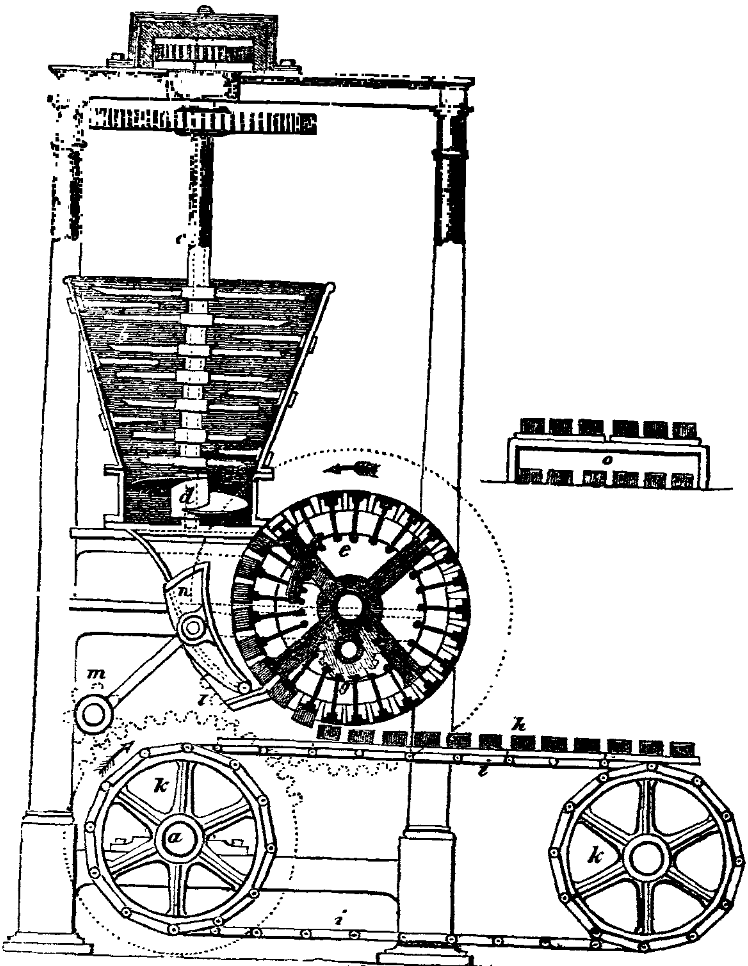


bottom plate *u*, the periphery of which being furnished with teeth or cogs, as shown, take into the teeth of a circular revolving plate *v*, over which, as the mould box passes, the lower surface of the bricks becomes smoothed. At *x* is a small frame, working up and down in a casing, with a pulley and counter-balance weight, like a sash window; it is raised by the crank *y* as each mould box passes, when three little boards are placed across the frame by a boy, for the reception of the bricks. When these are deposited by the means described,

the frame drops below the level of the endless strap *n*; the latter then receives them, and carries them off to their destination. At *z* is fixed a flat box, which acts as a gauge to regulate the thickness of the stratum of clay revolving upon the bottom plate *n* of the pug mill. The operation of this machine is as follows: the clay being worked in the ordinary manner through the pug mill, it passes out at the mouth, (not shown, being on the opposite side,) from thence under a flap which partly regulates the quantity on the bottom plate, and next under the gauge, which determines it precisely. A mould box having passed over the highest inclined plane or riser *k* first falls on the stratum of clay, and chops out three bricks, filling the moulds therewith by the false bottoms rising up to the determined point from the pressure of the clay against them; the moulds, with the bricks in them, then slide over the polishing plate *r*, (which is kept wet by water constantly dripping upon it from a tub); from thence the moulds pass on to the frame *x*, when the weight *q* strikes against the protruded bolts of the false bottoms, and pushes out the bricks upon the boards on the frame; the frame then descends two or three inches by their weight, and delivers the boards upon the endless strap, which, being constantly in motion, carries the bricks away to be deposited on the hacks. The mould box being discharged is then carried upon its roller up the first riser *k*, drops into the water, thence rises again, falls upon the cushion, next into the sand box, whence ascending again, the highest inclined plane being duly prepared, it falls again upon the bottom plate of the pug mill, and chops out three more bricks, during which period each mould box has operated in a similar manner.

We shall now proceed to describe the brick-making machinery invented by Mr. Leahy, and erected by him for the Patent Brick Company; it is represented in the accompanying figure. *a* is the main horizontal shaft in direct communication with the steam engine or other first mover; *b* is a hopper-formed vessel, technically termed the pug mill, in which the clay and other materials are tempered and mixed up: it is for this purpose furnished with cross iron bars, or blades of steel; part of these are firmly fixed to the *hollow* vertical shaft *c*, and the remainder bolted to the sides of the pug mill, and they are so arranged, that those fixed to the shaft cut in as they revolve between the others. The clay is delivered into the hopper or pug mill by an endless chain of buckets (in the same manner as ballast is raised in the Thames); it is then cut up and tempered by the knives and bars in the pug mill, and gradually descending, it falls, or rather is forced by the superincumbent pressure upon the circular inclined plane *d*, which consists of a single thread or spiral turn of a very large screw, occupying the whole internal space of the lower cylindrical end of the mill, where it is exhibited in section. This screw or circular inclined plane is fixed to the central shaft passing longitudinally the hollow shaft, and a slow reversed motion is given to it, by means of an intermediate wheel acting upon pinions in the upper part of the frame. The blades on the hollow shaft, revolve in the pug mill at the rate of fifteen turns in a minute, grinding and dividing the materials much more completely than in the ordinary mode of brick-making. In this attenuated state the materials are forced upon the circular inclined plane of the screw, and as this slowly revolves in a contrary direction at the rate of five turns in a minute, it takes hold of the clay (by a peculiar adaptation not easily described), and forces it out of the mill, in a very compact state, into a receptacle below: of this, one side is always in immediate contact with the moulds, and those two sides which are at right angles to the former side are closed by iron cheeks, between which the lever or forcing flap *n* acts by pressure, and, fitting closely, prevents the escape of the clay, so that it can only pass into the moulds. These moulds are placed round the periphery of a circular frame *e* made of flat iron rings, fixed upon bars or spokes, and turning upon a *fixed* shaft. There are twenty-five of these moulding boxes in one circle; but as the frame *e* may be of any breadth, it may contain twice twenty-five or thrice twenty-five on the circumference of the cylinder, provided that the engine is capable of affording sufficient power or force to cut or mould so many bricks at each revolution. Each moulding box is furnished with a false or movable bottom, to which rods are attached, for the purpose of pushing out the brick

when moulded, and drawing back the bottom to its place to receive a fresh portion of the clay. The manner in which these operations are performed is extremely simple and ingenious. The ends of each of the moulding-box rods are bent at right angles, and an eccentric piece *f* is so fixed, that, as the moulds revolve, and at the moment that the surface of each is covered by being in contact with the clay, it gradually draws back the false bottom, and with it the clay, which is also urged on by the circular inclined plane *d;* and to render the bricks solid and compact, a powerful pressure is applied to them by means of



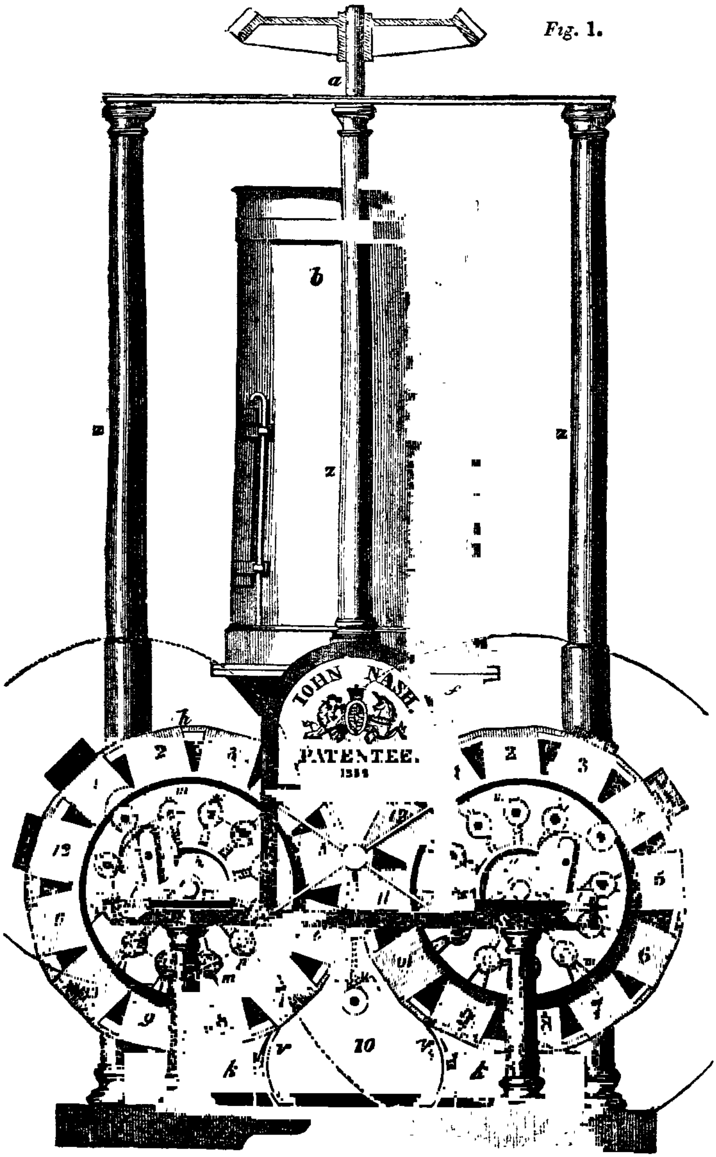
the flap forcer *n*, to which a backward and forward motion is given by the *thrusting* of a rod attached to a revolving crank. The moulding boxes, immediately they are thus filled, are subjected alternately to the action of a steel scraper, which levels and smooths their surface, and is made to operate by the pressure of springs. The bricks, now completely formed and fast in their moulds, pass downwards in their revolution, which brings the ends of the rods under the operation of a cylindrical roller, with grooves made round it at equal

distances; into these grooves the ends of the rods successively pass, which in their revolution force out the rods, and thereby push out the bricks from the moulds on to boards placed nnderneath to receive them. The bricks thus made are carried forward to the hacks or drying house, upon an endless web or chain *i i*, to which a continued motion is communicated by the revolution of the two polygonal drums or wheels *k k* placed at the requisite distance asunder. The upper part of the engraving shows a side elevation of the machine, and the lower part a section of it; and although these views serve to give a general idea of the construction of the apparatus, it has been impracticable to show the gearing by which the several motions are produced; we will therefore attempt to describe it as follows: Upon the horizontal shaft *a* (which makes 2½ revolutions per minute,) is fixed a toothed, bevelled wheel, which drives a bevelled pinion on an upright shaft (not shown); nearly at the top of this a spur wheel is fixed, which works into a pinion fixed upon the upper end of the hollow shaft *c*, which carries the knives or blades in the pug mill. Upon the upper end of this upright shaft is also fixed a pinion, which works into an intermediate pinion turning upon an axis. This intermediate pinion acts upon another pinion affixed to the internal shaft, communicating a slow and reversed motion to it, and also the circular inclined plane affixed to it; at the lower end, on the main horizontal shaft, is fixed a spur wheel *m*, which gives motion to the crank and to the flap forcer connected to it. *o*, in the separate figure, gives the form of the shelves comprising the drying apparatus,—Mr. Leahy proposing to dry bricks either by flues or by steam, instead of ranging them in hacks exposed to the variations and inclemences of the weather,—by which means it is presumed that the bricks will be rendered dry enough for burning, either in kilns or clamps, in a much shorter time than in the common method, and the process may be carried on in winter as well as in summer. If drying by flues be resorted to, a drying house must be furnished with proper stages, and shelves must be provided. Around and across the lower part of these, flues framed either of bricks or cast iron are to be placed, through which flame or heated air is to be conveyed. In drying by steam, the vapour is conveyed from the boiler through cast iron pipes throughout the drying house, and boards are arranged upon stages (similar to those in the separate figure), so as to leave intervals between the rows of bricks, and to prevent their touching one another.

Nash's Patent Brick-making Machinery. This invention, which we have now to describe, is the only one we believe that has yet been brought into successful operation;—owing probably to the circumstance of the patentee (who is a large tile and brick manufacturer at Market Rasen, in Lincolnshire,) having perseveringly applied that intimate knowledge of his art which can only be acquired by long practical experience. The leading features of Mr. Nash's mechanism consist in the application of separate or detached moulds of a particular construction to a series of mould boxes, which are consecutively brought into action, in the employment of heaters, placed in contact with, or contiguous to, the fresh bricks, during the process of their being moulded; and in lieu of sand, which is generally used to prevent the adhesion of the bricks to the moulds, employing elastic absorbent substances, such as cloth saturated with water. In the subjoined engravings, *Fig.* 1 represents a front elevation, and *Fig.* 2 an end elevation of the principal parts of the machine. A vertical shaft *a* is made to revolve in the cylinder or pug mill *b* by any adequate force acting upon the bevelled wheel *c*. A number of broad steel or iron blades *d d d* are attached to the shaft *a*, their surfaces being set at such an angle as will cause them during their revolution to pass nearly in contact with the edges of two other sets of knives *e e e* fixed on opposite sides of the cylinder, by which means the clay and other materials with which the mill is charged are tempered and amalgamated, and then forced into the hopper *f*, fixed to the lower extremity of the pug mill. This hopper is divided into two equal chambers by a vertical blade or knife, which separates the materials into equal portions, which are supplied to the moulds in a compact state. The moulds are lodged in rectangular cavities at equal distances in the periphery of two polygonal drums *g h*; these cavities are marked 1 to 12. To one face or side of the drums are

attached two toothed wheels, gearing into each other so as to revolve in opposite directions when motion is communicated to one of them. These wheels lying at the back of *Fig.* 1 cannot be seen, but one of them is shewn at *i* in *Fig.* 2. The moulds, after being filled with the plastic material, are pushed out from their

Fig. 1.



recesses by means of pistons at *m m*, easily fitting the recesses, and sliding upon parallel rods fixed to the rims of each drum. To each piston is attached, by a short rod, a cross head, sliding upon the parallel rods, and having at each end

small anti-friction wheels $p\ p$, which, by the motion given to the machinery, come in contact with a larger wheel q placed eccentrically, which thus raises

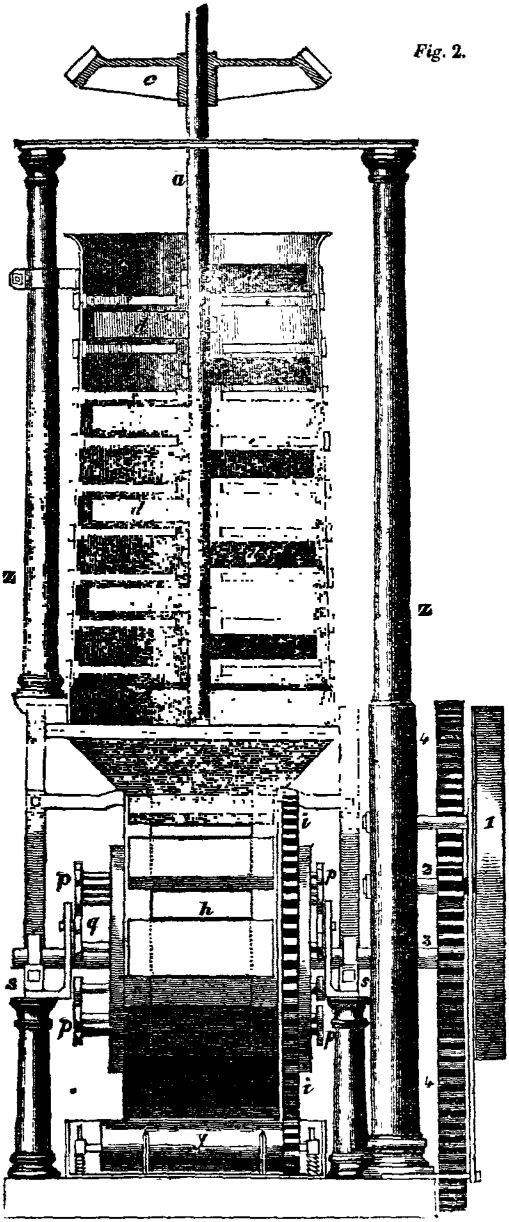


Fig. 2.

the pistons, and the moulds which lie upon them are then removed by hand and emptied. During this latter process the emptied mould receiver will have passed

over the centre of the eccentric wheel *q*, and the piston will be descending when the attendant places the emptied mould in its former situation, to be filled again from the hopper as it passes under it. Between each of the rectangular mould boxes are formed a series of wedge-shaped boxes, termed by the patentees "hollow sectors," into each of which is placed a red-hot iron, the object of which is to expel the superfluous moisture from the newly-formed brick, &c. in order that the manufacture may be conducted in the winter as well as the summer. These irons are heated in the kiln fires. The axes of the polygonal drums revolve in plummer-blocks, supported upon a strong frame *s*; but as the polygonal drums revolve in close contact, the plummer-blocks are free to slide in grooves in the frame, and the wheels are kept in contact by the action of strong helical springs *t*, which press against the plummer-blocks, the other end of the springs abutting against a regulating screw. In the middle of, and underneath, the horizontal frame *s*, is fixed a knife *u* (supported in its place by a spiral spring), which separates the whole or a portion of the superfluous materials from each mould, as the latter passes over the edge of the former. As some redundancy of material may still be left after the operation of the knife *u*, the exposed surface of the moulds in motion undergoes a similar treatment from two other knives *v v*, fixed to the foundation plate *w* of the machine. A trough or cistern *k k* containing water, is placed under each of the drums, the lowest sides of which come in contact with a cylinder *y*, covered with strong coarse cloth or other suitable absorbent substance, which, as it revolves, takes up the water and delivers it to the moulds, as before mentioned. These cylinders are mounted on elastic bearings, and derive their motion from pinions on their axes, actuated by the toothed wheels on the drums. In the centre of the foundation plate there is a cavity, or pit, for the reception of the superfluous clay or other materials, which are removed at pleasure. The pug mill has a door in it, for the convenience of cleaning it out when requisite; and the whole of the upper part of the machine is supported by three columns *z z z*. The polygonal drums are driven by a set of wheels lying at the back of *Fig.* 1, and therefore in that figure shown by dotted circles. *No.* 1 is a band wheel, which drives the rest; it is affixed to one of the columns, and has a pinion 2 attached to it, that drives a larger wheel 3, running loose on the shaft of one of the drums. This last propels another large wheel 4, fixed on the shaft of the other drum, gearing into each other; they are driven round together, but in opposite directions. Since our drawings of this machine were taken, we understand that the patentee has made some improvements in the arrangement of his driving wheel, which renders the action of the parts very steady and uniform. In case of negligence on the part of the boys, or other attendants of the machine, in not removing the bricks or tiles after the moulds containing them have passed the centre of the eccentric wheel, they fall back into their former position, and pass round to the place of delivery, as before, without any damage whatever being done to the machine. Having explained the general arrangement and operation of the machine, there remains to be described the construction of the detached moulds. *Fig.* 3 represents a side view, and *Fig.* 4 an end view, of one of these. The ends

Fig. 4.

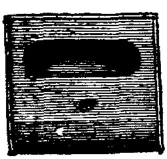
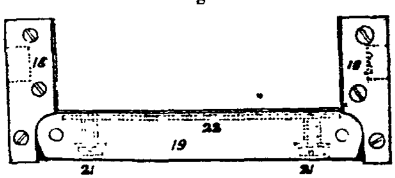


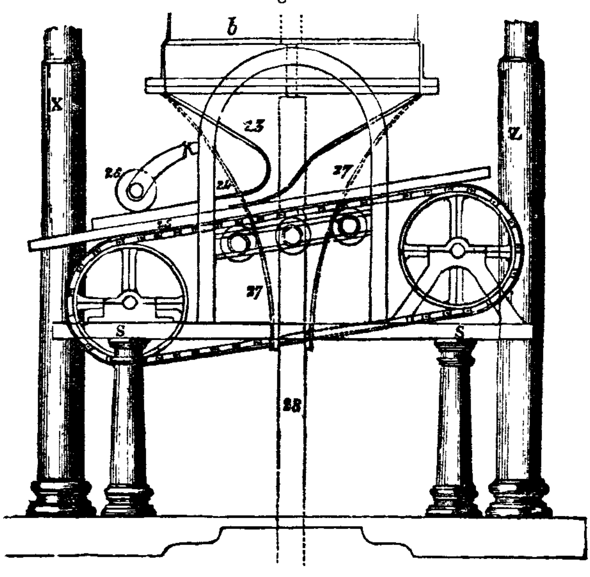
Fig. 3.



of the mould 18, 18, are made of wood, plated at the edges with iron, and fastened on by screws, as seen in *Fig.* 3. The bottom 19 is also of wood, but cased in a strong frame of cast iron, and at its two extremities are jointed to the ends 18, 18, so as to open only a little way, for allowing the brick to separate freely from it

upon inverting the mould. This effect is facilitated by lining the interior of the mould with cloth, which, although constantly in a wet state, admits air to pass through its interstices when the clay is forced into the mould, so that when the brick is afterwards forced out, the moisture of the cloth, and the spring of the confined air, delivers the brick uniformly clean, without the adhesion of any clay. It will be observed that the two ends 18 of the mould have each a cavity; these cavities receive the fingers of the workman when he takes hold of the mould, which he afterwards inverts, drawing back the ends 18 at the instant, and pressing with his thumb upon the screw heads 21 21, the other ends of which are attached to a plate 22 underneath the cloth lining of the bottom, as shown by dots, causing the brick to be immediately disengaged. The two sides of the brick not included in the detached mould are formed by the partition between the mould boxes and the hollow sectors. The forms and dimensions of the detached moulds are varied according to the nature of the articles to be produced therefrom. For adapting the machine to make tiles, or other articles of a greater length than a brick, two movable blocks, which usually lie inside the hopper, to contract its lower dimensions, are taken out. In the making of drain tiles, and other articles having cavities within them, jointed horses or cores are employed; the plastic matter is forced around them by the action of the machine in the same manner as in forming a brick, and the subsequent operations are also the same, except that in the removal or delivery of such tiles from their moulds, suitable adaptations are made to prevent their being pressed or even touched by the hand. The annexed *Fig.* 5 exhibits another arrangement employed by Mr. Nash for making flat tiles, flooring tiles, &c. of any required breadth and thickness. This cut only represents the lower

Fig. 5.



part of the machine, the upper being the same as in the previously described apparatus. To the bottom of the pug mill is fixed a funnel-shaped hopper 23, the materials in which, after being forced through a mouth 24, formed of the required shape, are received upon boards 25, and when cut to the proper length, are removed to sheds for drying. In order to equalize the surface of the clay after it has come out of the hopper, a roller 26 turning in bearings on a curved arm, which is fixed to a hinge joint, gives to the material any pressure that may

be required, by loading it accordingly. The dotted lines 27, 27 in the same figure, exhibit another funnel-shaped hopper, for the purpose of making pipes or tubes, by means of a centre core 28, between which and the cylindrical continuation of the hopper, the material is forced by the action of the pug mill, and produces a tube, which, after having made a certain length of, is cut off, the tube being turned round, to render the inside smooth previously to its being removed. The patentee states that this machine may be used with either one or two horse power; that when used with one horse power, the product is about 700 per hour, or 8000 per day; to do which requires the services of two men and eight boys, occasioning an expense not exceeding two shillings and sixpence per 1000. With two horse power employed, the production is double, or 16,000 per day; but the quality of the bricks, which the editor has seen, is equal to those which are usually finished by grinding the surfaces by hand. The saving of labour in the production is about two shillings per 1000; but the quality rendering them worth five shillings per 1000 more in the market, the advantage of making by the machine, where good bricks are required, is equal to seven shillings per 1000.

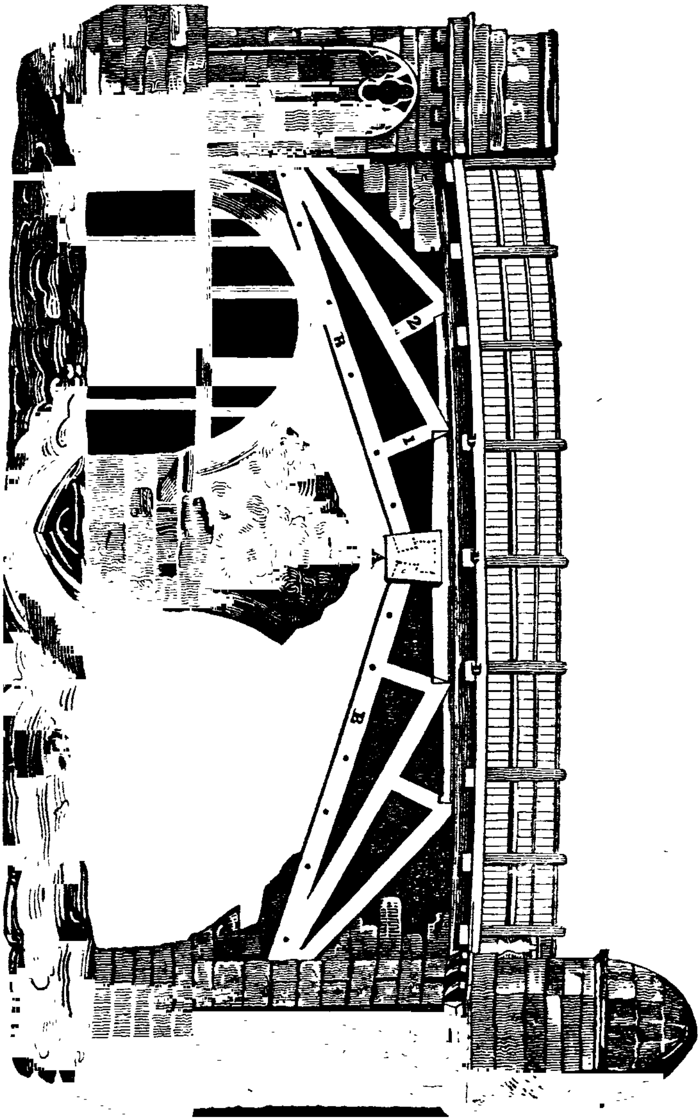
BRIDGE. A structure with one or more transverse apertures, raised for the convenience of passing a river, canal, valley, &c., and formed of various materials, as timber, stone, iron, &c. It is highly probable that the first bridges were composed of lintels of wood stretching from bank to bank, or, if this were impracticable, resting on piers or posts fixed in the bed of the river; and in China many considerable structures of this kind are still to be seen. As experience showed the defects of these early attempts, improved modes of construction naturally followed. In a strong current, the frequent piers or posts necessary for the support of lintels, would, by contracting the water way, increase it to a torrent, obstructive of navigation, and ruinous to the piers themselves. In constructing bridges over rapid rivers, it would, therefore, be found essential to their stability that the openings between the supporters should be as wide as possible, and every facility given to the free passage of the water; and as this could only be effected by arches or trusses, there can be no doubt that these inventions were perfected before bridges became common. The most ancient bridges which we know of, are the work of the Romans, unless we except some of the stone bridges in China, with whose antiquity we are unacquainted; some of these latter are turned on arches in the usual manner, and others built with stones from 5 to 10 feet in length, so cut as each to form the segment of an arch. The Roman bridges generally consisted of a horizontal road, supported on one or more semicircular arches. Of the bridges of antiquity, that built by Trajan across the Danube is allowed to have been the most magnificent. It is described by Dion Cassius as consisting of twenty piers of squared stone, each of them rising 120 feet above the foundations, 60 feet in width, with a water way between every two of 170 feet, which was consequently the span of the arch, so that the whole length of the bridge was nearly 1,500 yards. It was destroyed by Adrian, lest it should afford a passage to the barbarians into the empire, and some of the piers are still to be seen near the town of Warkel, in Hungary. The next considerable Roman work of this kind is the Pont du Garde, which serves the double purpose of a bridge over the Gardon, and an aqueduct for supplying the people of Nismes with water. The bridge, which consists of six arches, is 465 feet in length, and supports a second series of eleven arches, which are continued beyond the extremities of the bridge, and form a junction with the slope of the mountain on each side; it is about 780 feet long. Over these is a third series of thirty-five arches, much smaller than those below, 850 feet in length, supporting a canal on a level with two mountains, along which the water is conveyed to Nismes by a continued aqueduct. This extraordinary edifice is built with very large stones, held together by iron cramps without cement, and remains in excellent preservation to the present day. The whole height is 190 feet above the lower river. We may also briefly notice the bridge of St. Esprit, near Lyons, which is of Roman origin, and is 800 yards in length; it is very crooked, and bends in several places, forming many unequal angles in those parts where the river has the strongest current. The bridge over the Tajo, at

Valenza de Alcantara, about 25 miles from Madrid, built in the time of Trajan, is raised 200 feet above the water, is 670 feet in length, and consists of only six arches. Near the old town of Brionde, in the department of the Upper Loire, is a stupendous bridge of one arch, the largest with which we are acquainted. The span of the arch is 181 feet; its greatest height from the level of the water to the intrados 68 feet 8 inches; and the breadth 13. It is attributed to the Romans The following are amongst the most celebrated bridges of modern date: The bridge of Avignon, over the Rhone, begun in 1176, and finished in 1188. It consisted of eighteen arches, and was about 1000 feet in length. It was destroyed by a violent inundation of the Rhone in 1699; many of the ruinous decayed arches still remain. The Rialto, at Venice, was begun in 1588, and finished in 1591, after a design of Michael Angelo Bonarotti. It consists of a bold flat arch, nearly 100 feet wide, and only 23 feet in height from the level of the water. The aqueduct bridge of Alcantara, near Lisbon, begun in 1713, and finished in 1732, consists of thirty-five arches, of various dimensions; the eighth is the grand arch, which is 108 feet 5 inches in the span, and 227 feet in height; the other arches run from 21 feet 10 inches to 72 feet in width; the total length of the piers and arches is 2464 feet. The bridge of Neuilly, which crosses the Seine, built between the years 1768 and 1780, by M. Perronet. It is level on the top, and consists of five equal arches, 128 feet (English), with a rise of 32 feet (English). The arches, which are elliptic, are composed of 11 arcs, or circles, of different diameters. The upper portion of the arch was formed with a circle of 160 feet radius, but after removing the centres, became flattened to an arc of a circle of 259 feet radius, the rise of the curve in a length of 33 feet amounting to no more than 6 inches. The bridge of Orleans, over the Loire, built by M. Hupean, between the years 1750 and 1760. It comprises nine oval arches, described from three centres which spring at 12 inches above low water. The centre arch is 106 feet span, with a rise of 30 feet; the others gradually decrease in width as they approach the shores. The whole length of the bridge is 1,100 feet. We shall now proceed to notice some of the most remarkable bridges in our own country, beginning with those of the greatest antiquity. The Gothic triangular bridge of Croyland, in Lincolnshire, is supposed to be the most ancient structure remaining entire in this country, and for singularity of construction and boldness of design may vie with any bridge in Europe. It was erected about the year 860, and is formed by three semicircles, whose bases stand in the circumferences of a circle, equidistant from each other, and uniting at top. The ascent on either side of the semicircular arches is by steps paved with small stones, and so steep that foot passengers only can go over the bridge. The first bridge over the Thames at London was of wood, and was built in the reign of Ethelred II., between the years 993 and 1016; in 1163 it was repaired, or rather rebuilt of timber; and in 1176 the late stone bridge was begun under Henry II., and was finished in the reign of John, A.D. 1209. It had originally twenty small locks or arches. The length was 940 feet, the height 44, and the clear width between the parapets 47 feet. In 1758 the bridge underwent a very extensive repair, and two of the centre arches were thrown into one. The piers were from 15 to 35 feet thick, with enormous starlings projecting on each side, so that when the tide was above the starlings the greatest water way was only 540 feet, scarcely half the breadth of the river; and when the water was below them, the water way became reduced to 204 feet, causing a most dangerous fall at low water. In 1823 further repairs having become necessary, and the obstructions which the old bridge opposed to the navigation of the river becoming the subject of much complaint, an Act of Parliament was obtained for the construction of a new bridge, of which we shall presently give a full account. The longest bridge in England is that built by Bernard, abbot of Burton, over the Trent, at Burton, in the twelfth century. It is all of squared free-stone, is strong and lofty, and is 1545 feet in length, consisting of thirty-four arches. One of the most extraordinary bridges in Great Britain is that over the Taaf, in Glamorganshire, called, in Welsh, *Pont y ty Prydd*, built by William Edwards, an uneducated mason of the country. Two bridges which he had constructed at the same spot had failed; the first, after standing 2½ years

had been carried away by a sudden and extraordinary rise of the Taaf, swelled by heavy rains and considerable tributary streams; the second failed in consequence of the ponderous work over the haunches forcing out the key stones before the parapet was finished. Undismayed by these misfortunes, Edwards resumed the attempt, and by means of cylindrical holes through the haunches, so reduced their weight, that there was no longer any danger from them; and the third bridge, which he completed in 1751, has stood ever since. The present bridge consists of a single arch of 140 feet span, and 35 feet high, being a segment of a circle of 175 feet diameter. In each haunch there are three cylindrical openings running through from side to side. The diameter of the lowest is 9 feet, of the next 6 feet, and of the uppermost 3 feet. The width of the bridge is about 11 feet. To strengthen it horizontally, it is made widest at the abutments, from which it contracts towards the centre by seven offsets, so that the roadway is 1 foot 9 inches wider at the extremities than in the middle. The bridge over the Thames at Westminster, was constructed by Mr. Labalye. It is 1,220 feet long, and 44 feet wide, and consists of thirteen large, and two small arches. The span of the centre arch is 76 feet, that of the next is 4 feet less; and in the others it goes on progressively decreasing 4 feet in each, except the two small arches, which are 25 feet each The arches are semicircular, and spring from about 2 feet above low water mark, leaving a free water way of 870 feet. It was opened to the public in 1750, and cost 218,800*l.* Blackfriars bridge was planned and built by Mr. R. Mylne, between 1760 and 1771. It is 999 feet long, and 43 feet 6 inches wide, and has 9 elliptical arches. The centre arch is 100 feet, and the four arches on either side decrease gradually towards the shore, being 98, 93, 83, and 70 feet respectively, leaving a clear water way of 788 feet. The cost of erection amounted to 152,840*l.* Numerous neat and elegant stone bridges have since been erected in various parts of Great Britain and Ireland. Of these we shall briefly mention the Tees bridge, at Winston, in Yorkshire, consisting of a single arch of 108 feet span, designed by Sir T. Robinson; one at Kiln, of five elliptical arches, of 72 feet span each; and the aqueduct bridge on the river Lune, consisting of five arches of 70 feet span, both by Mr. Rennie; Essex bridge, Sarah's bridge, and Carlisle bridge, each over the Liffey; that at Aberdeen, designed by Mr. Telford; and another, over the Dee, by the same gentleman. But the most magnificent structure of the kind in this country, and, possibly, in Europe, is that across the Thames, nearly midway between Blackfriars and Westminster bridges, named Waterloo bridge. The project for a bridge at this part of the river originated with Mr. G. Dodd, about the year 1805, but from the opposition made by various parties whose interests were affected by the scheme, it was not until June 1809 that an Act of Parliament was obtained, incorporating a company for carrying the idea into effect; and Mr. Rennie having been appointed engineer to the company in June, 1810, he furnished two designs, one of seven, and the other of nine arches, the latter of which was finally approved by the committee, and ordered to be put in execution. This noble bridge has a level roadway, and contains nine elliptical arches, each having a span of 120 feet, and a rise of 35 feet, leaving a clear height of 30 feet above high water spring tides, and forming a water way of 1080 feet. The length of the bridge between the abutments is 1380 feet, and its width between the parapets 42 feet 4 inches. The roads or approaches to each end of the pier are 70 feet wide throughout, except just at the entrance from the Strand, and are carried over a series of semicircular brick arches of 16 feet span each. The approach on the Surrey side is formed by thirty-nine of these arches, besides an elliptical arch of 26 feet span, over the Narrow-Wall road, and a small embankment about 165 yards long, having an easy and gradual ascent of not more than 1 foot in 34.

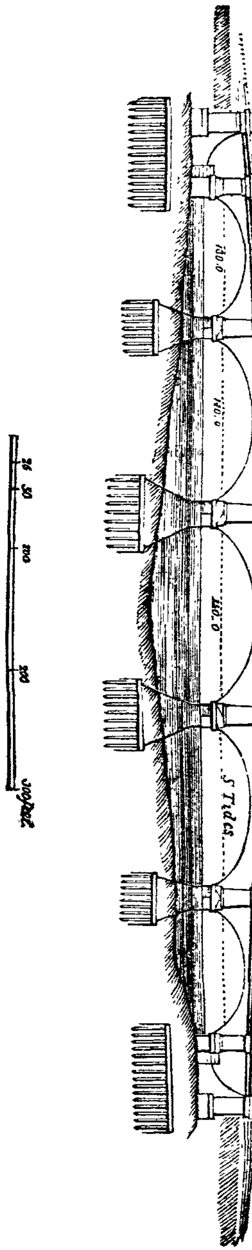
The length of the brick arches in the Surrey approach is	766 feet.
Ditto . . . . Strand approach .	310
Length of bridge between the abutments	1380
Total length of bridge and brick arches . .	2456 feet.

It should be mentioned as a proof of the excellent manner in which this noble structure has been executed, that on removing the centering, the greatest settlement did not exceed $1\frac{7}{8}$ inch, which is unprecedently small in arches



of such great span. We shall now proceed to notice the New London bridge, erected by the present Mr. John Rennie, from the design of the late Mr. Rennie, his father, who died shortly before the work was commenced. According to the original plan, the new bridge was to have been built on the

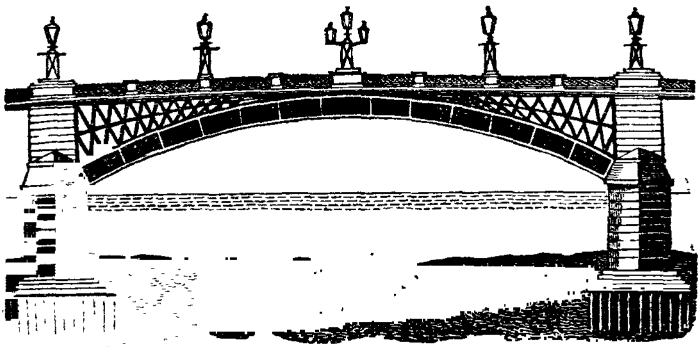
site of the old one, but the corporation of London decided that the bridge should be built 180 feet higher up the stream. The bridge was also made 6 feet wider, and the abutment arches carried 2 feet higher than in the original design. The foundations of the bridge were laid in coffer dams, and the first pile for the dam of the south pier was laid March 15, 1824. As the works proceeded, it was found expedient that two of the small arches of the old bridge, on each side, should be thrown into one, to compensate for the additional obstruction which the works occasion to the navigation of the river. This was effected with such skill, that the usual traffic was never once interrupted during the operation, the heaviest carriages passing over the bridge, and vessels passing through it, with the same facility as before; whilst such was the promptitude and despatch used, that the whole operation only occupied six weeks. The engraving on page 267, with the following description, will explain the manner in which the alteration was effected. The roadway was first boarded in and taken up one half at a time, and a space cleared away for the reception of a transverse iron girder A. A set of transverse timber principals B B was then laid on to this girder from the extreme piers of the two arches, bestriding, as it were, the central pier, which was to be removed; and these, instead of being placed at intervals as in roofs, were all fixed and bolted close together from one side of the roadway to the other, forming one unbroken mass of timber. Above the girder there was inserted what may not be unaptly termed the brestsummer C, into which the purlins D D were mortised at intervals for the support of a substantial planking, on which the pavement was laid as before. The strength of the truss-work was farther augmented by a number of counter-principals, as 1, 2, some of the struts being fixed close together, and others with an interval of one width between them. The bridge itself was nearly completed before the line of the approaches to it were decided upon; it was at length finally settled that the approach on the London side should commence at Cannon-street, Eastcheap, passing over Thames-street by means of a dry arch, and that on the Borough side the road should form an inclined plane, supported on a series of brick arches, commencing near St. Thomas's Hospital, with a large dry arch facing Tooley-street. On the 1st of August, 1831, the bridge was opened to the public, the period occupied in its erection from the time of driving the first pile, being seven years, five months, and thirteen days. The engraving in the margin is an elevation of the new bridge; it is formed of



five semi-elliptical arches, the least of which is larger than any other elliptical stone arch ever before erected. The centre arch is 152 feet span, with a rise

of 29 feet 6 inches above high water mark; the two arches next the centre are 140 feet in span, with a rise of 27 feet 6 inches; and the two abutment arches are 130 feet span, with a rise of 24 feet 6 inches; thus the clear water way at all times of the tide is 692 feet, which is above 60 feet more than the old bridge afforded at high water mark. The whole length of the bridge from the extremities of the abutments, is 928 feet; within the abutments, 782 feet; and the width between the parapets is 53 feet. The engraving represents the new bridge.

Towards the close of the eighteenth century some bridges were erected, the arches of which were constructed entirely of cast iron. The honour of this invention is due to this country, and the first of these structures was the bridge over the Severn, at Colebrook Dale, erected by Mr. Darby, in 1779. Some years after (about 1790,) the celebrated Thomas Paine had one constructed at the same place, which he intended for America, and which was put together in a meadow near that place; but he not being able to pay for it, it was taken down, and part of the materials were employed in the construction of the Sunderland Bridge, erected by Mr. Burdon over the river Wear, in 1793. Subsequently, numerous iron bridges have been erected: the principal ones are Buildwas (Colebrook Dale Company), 1795-6; Tame, Herefordshire (failed), 1795-6; Parret, at Bridgewater, 1796; Staines (twice failed), 1800; Tees, at Yarm (failed); Boston, in Lincolnshire; New River at Bristol (two); Vauxhall Bridge, over the Thames; but the most celebrated of these structures is the magnificent one over the Thames, called the Southwark Bridge, designed and erected by the late Mr. Rennie. This noble bridge consists of three circular arches of cast iron, supported by piers of granite; the centre arch is of 250 feet span, and the side arches 210 feet each. The piers are 24 feet thick. The bridge is 718 feet long between the abutments, and 42 wide between the parapets. There is a dry arch over the road on the Southwark side. The work was begun in 1814, and completed in 1824. The annexed cut is a view of the centre arch.



Iron Suspension Bridges were in use in Europe at the time of Scamozzi, the architect, who mentions them in his work *Del Idea Archi*, 1615; but the knowledge requisite to determine the properties of this kind of bridge was not published till the time of Bernouilli. Suspension bridges are described as existing in various parts of Asia, Africa, and America, before this species of construction began to be practised in Europe. The first chain bridge erected in England is supposed to be that over the Tees, forming a communication between the counties of Durham and York. Since that time the number of these structures has been increasing, some of which, in size and magnificence, exceed any thing of the kind in the known world. Of these, the most celebrated is the one recently erected over the Straits of Menai, by Mr. Telford. The bridge consists of one opening of 560 feet between the points of suspension, and 100 feet in height between the high-water line and the under side of the road-way, which is horizontal. In addition, there are four arches on the western side, and three on the eastern side of the main opening, each of 50 feet span.

The roadways consist of two carriage ways, each 12 feet in breadth, with a foot-path of 4 feet between them, so that the platform is about 30 feet in breadth. The whole is suspended by perpendicular iron rods, from four lines of strong cables of malleable iron, passing over a pyramidal support or pier, at each end of the main opening, the versed sine of the curve being 37 feet, or about $\frac{1}{15}$ of the chord line or span. The weight of the bridge between the points of suspension, including the weight of the cables, is 489 tons, and the suspending power being calculated at 2,016 tons, leaves a disposable force of 1,674 tons to meet any stress the bridge may be exposed to. The-iron bar suspension bridge erected

Fig. 1

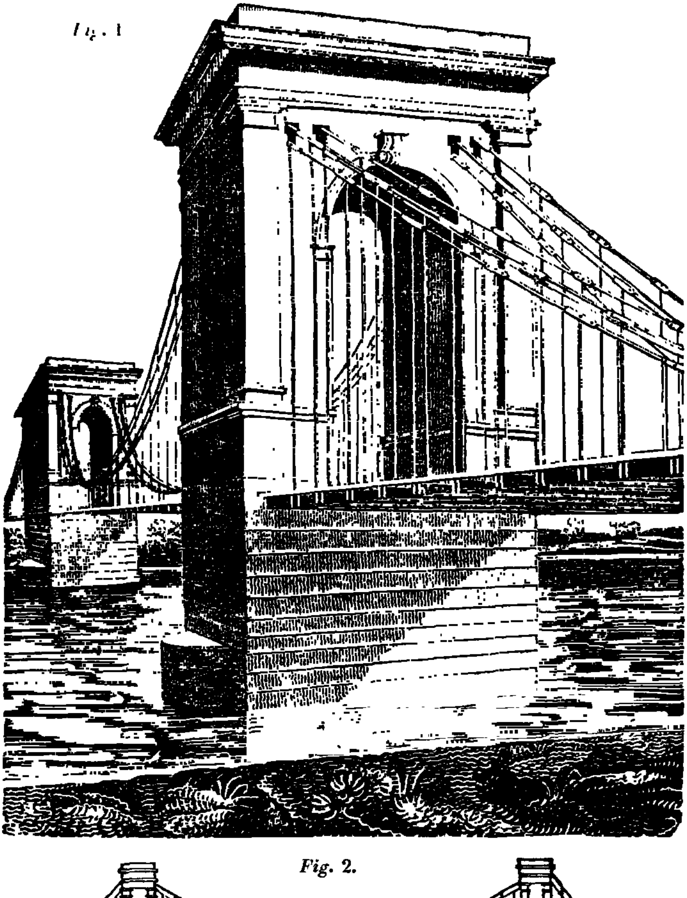
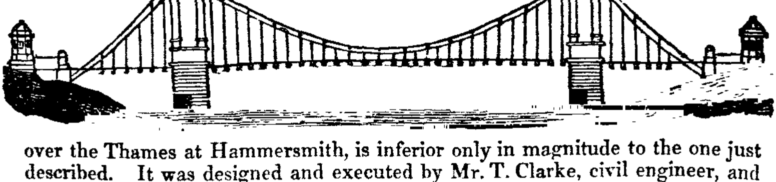


Fig. 2.



over the Thames at Hammersmith, is inferior only in magnitude to the one just described. It was designed and executed by Mr. T. Clarke, civil engineer, and was opened for public use in August, 1827. The above cut *Fig.* 1, represents a perspective view, and *Fig.* 2 an elevation of the bridge, and some of the

details of its construction. This bridge consists of two suspension piers or towers, built in the river, having an opening of 400 feet between them. On the opposite shores are two strong abutments, over which a nearly level roadway passes through archways in the suspension towers. It is suspended by four lines of strong chains, hanging in curves from the abutments over the towers, and down between them, the roadway being supported from them by vertical rods. The principle of construction is as follows: D D *Fig.* 3, are the suspension chains, which consist of bars of iron 5 inches deep by 1 in thickness; these are 10 feet in length, and connected together, as shown in the plan beneath, by plates of iron having a strong bolt passing through them, and turned at the ends; these saddle pieces are placed ten feet asunder, and are so arranged that those in the upper chain are not immediately over those in the lower chain, but over the middle space between each two on the lower chain. From each saddle piece in each of the chains hangs a suspending rod C C, $1\frac{1}{4}$ inch thick, so that they are 5 feet asunder. The suspending rods are furnished with a joint where they are inserted into the opening between the chains or plates, enabling them to accommodate themselves to any extraordinary weight on the bridge. At the height of about 40 feet from the roadway, the chains pass through the masonry of the archways before mentioned, and over friction rollers, and are secured to the ballast plates *Fig.* 4, which are sunk to a considerable depth behind the abutments. The roadway consists of transverse beams in two thicknesses, $4\frac{1}{2}$ by 12 inches, with an interval of $2\frac{1}{2}$ inches between them; these

Fig. 3.

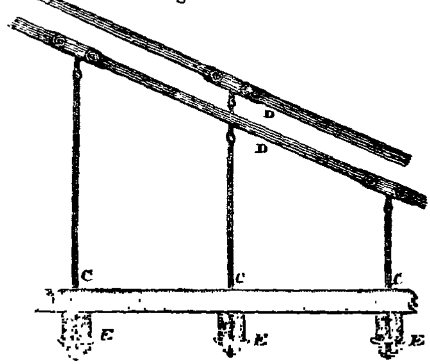


Fig. 4.

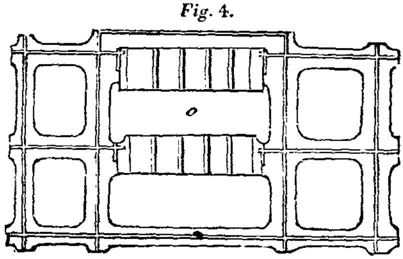
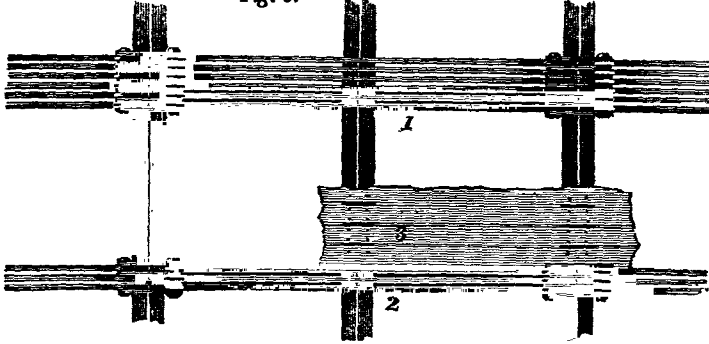


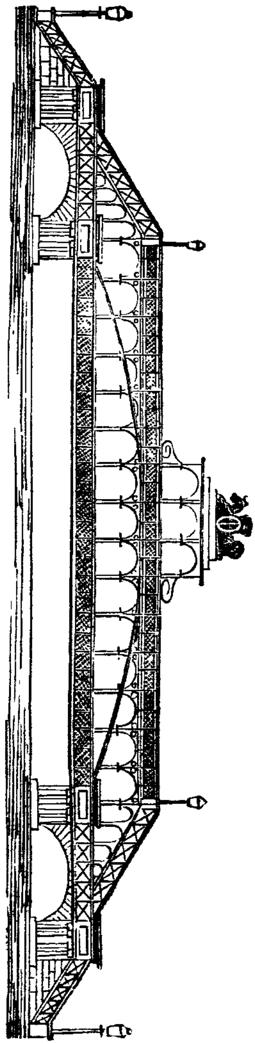
Fig. 5.



are fastened at the bottom by keys to strong iron plates; along each side of the bridge extends a pair of strong beams, which are firmly bolted to the flooring joists; this connexion is shown at E E, *Fig.* 3. The roadway of the bridge is

slightly raised towards the centre of the river, and the whole is boarded longitudinally with 3-inch planks, as shewn at *Fig.* 5, with a small space between each to prevent any water from settling on the bridge. There are two pairs of chains on each side of the bridge; the inner pair consists of six links or bars, and the outer of only three, as represented in *Fig.* 5. The total length of the bridge is as follows:—

	Feet.	Inches.
The central opening	400	3
The two suspension towers, each 22 feet . .	44	0
The opening on the Surrey side	145	6
The opening on the Middlesex side	142	11
The two abutments, each 45 feet	90	0
Total	822	8

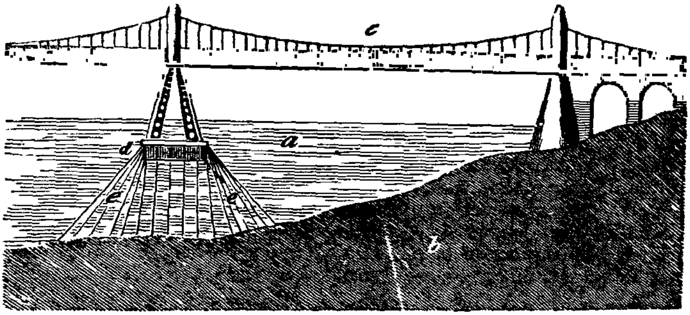


The towers are 48 feet high above the level of the roadway, 22 feet wide, and 42 feet broad. The roadway is 16 feet above the water, and consists of a carriage-way 12 feet wide, and two foot-paths, each 4 feet wide. The versed sine of the curve of the suspending chains is 29.6. Several bridges on the suspension principle, composed of iron wire, have also been erected, and on a small scale will no doubt answer; but if of great extent, the vibration becomes so great as to render them unsafe. Some of these, instead of being suspended from chains hanging in a curve between their points of suspension, are supported by diagonal braces, proceeding direct from the supporting towers to different parts of the platform forming the roadway. The wire bridge of Dryburgh, which was constructed in this manner, had one of its largest radiating chains broken off at the point of suspension, by some mischievous persons shaking it violently. Shortly after it was repaired, a high wind again broke the chains, and completely destroyed the bridge. From the evidence of many persons, it appeared that in this gale the vertical motion of the bridge was equal to its lateral motion, and was sufficient to precipitate a person into the river. The bridge has been since replaced by one on the Catenarian principle. At Vienna there has been erected a steel suspension bridge over the Danube. The span is 234 feet, and the versed sine 15 feet. It is the work of M. Ignace Von Mitiz, who calculates that the total weight of steel is less than half the weight of iron which would be necessary for a bridge of the same dimensions.

A model of an iron suspension bridge, upon a new construction, was exhibited in the year 1829 It was constructed by Mr. Mottley as a design for a bridge across the Thames, from Scotland Yard, on the Middlesex side, to the King's Arms, on the Surrey shore. The annexed design for an ornamental bridge for parks or pleasure-grounds, will serve to explain the nature of Mr. Mottley's plan, which consists in a combination of the principles of tension and compression. The arch represented by the curved line is confined between two parallel lines, and those lines are connected together by vertical bars, to which the

arch is inflexibly attached, and the parallel lines or bars also inflexibly jointed, and the whole combined by strong bolts at the top and bottom of every vertical bar, rendering it a skeleton of a trussed beam; thus affording an opportunity of having two paths across a river, the lower one of which may be used as carriage way, and the upper may serve for a footway or promenade. This second floor is not an absolutely necessary part of the structure; but if it be not adopted, it will be needful to have diagonal braces placed horizontally to stiffen the upper part. By this mode of construction, it will be seen that the stress or pressure instead of acting upon the highest point of the structure (as in the case of bridges where the main chains pass over lofty towers) exerts its force at the lowest point, viz. at the springing of the supporting arch, whilst the piers have only to support the *weight* of the bridge, the *thrust* being counteracted by tie bars, which connect the two extremities of the arch.

The accompanying engraving represents a portion of a bridge, or of a jetty, supported upon floating piers, as proposed by Messrs. Delafons and Littlewort,

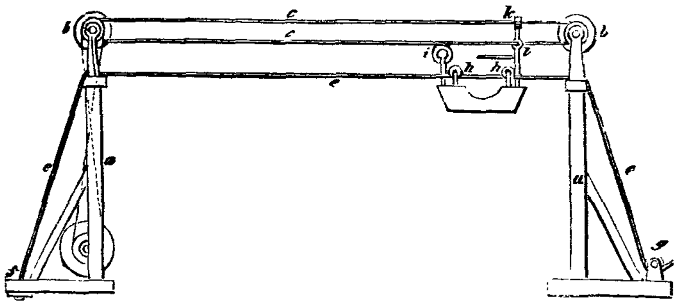


for situations where the water is too deep for the erection of piers, and where the expanse of water is too great to be passed over by chains, without any other support than that at the abutments. *a* represents the river or channel to be crossed; *b* the bed of the same; *c* the suspension bridge; *d* one of the floating piers, of which there may be any number, according to the distance between the shores; *e* the mooring chains, which are attached to the heads of piles driven perpendicularly into the earth. The piers are supported upon rows of properly constructed boats, whose buoyancy is sufficient to bear the weight, that is, without their being submerged at low water; and these boats are confined in this situation by the mooring chains. By this arrangement, when the tide rises, the piers cannot ascend and lift the bridge, which would be the case were the boats not tied down to the extreme point of low water, while the bridge is supported by their buoyancy in either case. The machinery by which the piles may be driven at considerable depths under water, forms the subject of a patent taken out by Messrs. Delafons and Littlewort.

The readiest, and probably the most ancient material for the construction of bridges, is timber; and, in most countries, wooden bridges are common; but, in their construction, Germany and America appear to take the lead of all other countries. The most celebrated of these structures was that over the Rhine at Schaffhausen, which was destroyed by the French in 1799. It was designed and executed by Ulric Grubenman, a common carpenter, who produced a model of a bridge to consist of only one arch of 364 feet span; but the magistrates insisting that the bridge should, near its middle, be supported by a pier, the remains of a former bridge at the same place, he seemingly complied, but executed the work in such manner as to leave it doubtful whether the bridge really received any support from the pier. John, the brother of Ulric, about the same time constructed a timber bridge of the same sort at Kuichenaw, 240 feet in length; and they afterwards conjointly constructed one near Baden, of 200 feet in length, and another at Wuttenghen, 198 feet in length. Several timber bridges were erected in Germany during the years 1807, 1808

and 1809, by Wiebeking. The widest span is that over the Regnitz, at Bamberg, which is 208 feet. There have been many capital timber bridges constructed in America. The Trenton bridge, over the Delaware, built by Burr in 1804, is a segment of a circle of 345 feet diameter, its chord measuring 200 feet, its versed sine 32 feet, and the height of the timber-framing at the vertex only 2 feet 8 inches. That called the Colossus, over the Schuylkill at Philadelphia, is of the extraordinary span of 340, and is the segment of a circle of 1465 feet diameter; its versed sine being only 20 feet, and height of the wooden framing of the arch at the vertex only 7 feet: it was finished in 1813.

Bridges of Boats are made of boats composed of either copper, tin, or wood, fastened across the stream by means of anchors or stakes, and laid over with planks. At Beaucaire, Rouen, and Seville, are very fine stationary bridges of boats, which rise and fall with the tide; that at Rouen is nearly 300 yards long, and paved with stone, so that laden carriages and horses go over it in safety. Another kind of bridge of boats is that called flying bridges, the use of which is mostly confined to those rivers in which the stream is always running down. A flying bridge generally consists of one or more boats, covered over by a platform, and connected by a long cable to an anchor midway of the river, and considerably higher up the stream than the landing place on either side; upon putting the helm over to one side, the side of the boat is presented obliquely to the stream, which impels it across the river to the opposite shore. Sometimes, instead of laying down an anchor in the stream, two stout shears or masts are erected, one on each bank, and firmly secured by guys. A stout hauser is then stretched tight from the top of one mast to the top of the other. Upon the hauser is a large iron ring or grommet, to which is attached one end of the boat rope, the other end of which is made fast to the boat, or boats, of which the bridge is composed. By the action of the tide upon the rudder the boat is sheered across the stream, dragging the grommet along the hauser. The annexed cut



represents another species of flying bridge, which has been proposed for crossing valleys, rivers, &c. It consists of a strong wire chain, iron rod, or cord *e e e*, which passes over the supports *a a*, to which one of the ends is firmly fixed as at *f*, and adjustable by tightening screws as at *g*; *c* is an endless cord passing over the pulleys *b b* on the supports and round the pulley *i*, which is attached to a light car, in which the passengers sit. The car is supported on *e e e* by the pulleys *h h*; it is attached to the endless cord by the stem *k l*, which is furnished with two holes to admit the cords at *k* and *l*. These holes pass through the stem at right angles to each other, so that when the upper hole *k* is placed in the direction of the cord, it will pass freely along it, while the lower hole is placed across the cord, and thereby holds it fast, and the car is dragged along by it: but if the stem be turned (which may be done by the handle at *l*,) the reverse operation will take place, and the vehicle will be dragged along by the upper cord. The endless cord may be put in motion either by persons in the car turning the pulley at *i*, or by persons turning the wheel at the station *f*, which is connected by an endless chain or band to the pulley *b*.

BRILLIANT. The purest kind of diamond; which see.

BRIMSTONE. See SULPHUR.

BRINE. Water impregnated with saline particles, and is either native, as in the sea and in salt springs, or it is artificially formed by dissolving salt in water.

BRONZE. A mixed metal, consisting chiefly of copper, with a small proportion of tin, and sometimes of other metals. It is used for casting statues, cannons, bells, and other articles, in all of which the proportions of the ingredients vary. See ALLOY.

BUILDING is the art of constructing edifices, the decorative part of which has received the more imposing name of Architecture. As the main design of this work is, however, to furnish the most extended accounts within its limits of the mechanism and manufacturing processes of the empire, we shall confine ourselves to the sketching of a mere outline of this subject, and refer the reader to those works from which he may fill up the details. The origin of all buildings may be deduced from the construction of the meanest huts. Small trees tied together at their tops, or connected by poles, and then covered with such materials as nature most readily presented, as brushwood, turf, leaves, and grass, were probably the primitive habitations, in temperate climates, of uncivilized man; indeed, such rude fabrics are still used by various tribes of Indians of the present day. As population increased, and agriculture improved, it became necessary for the inhabitants of woods to seek situations in the open country more favourable to their occupations; hence other means for constructing their dwellings became necessary; and finding the advantage of living in society, gradual refinements took place: amongst these, the employment of stone as a preferable material to wood for the floor and the roof. By degrees, elegance succeeded to, and was combined with, convenience. The earliest regular buildings of which any information is given, were erected by the Egyptians. The Assyrians and Persians added splendour and richness to the architecture of Egypt, but it was reserved to the Greeks to impart to this art elegance and symmetry; to them we are indebted for three out of the five orders of architecture, namely, the Doric, Ionic, and Corinthian. The Tuscan and the Composite orders, which complete the five, are rejected by some writers on architecture, because they differ but little from the other three. The Tuscan resembles the Doric deprived of some of its mouldings; and the Composite differs from the Corinthian by the introduction of the Ionic volute into its capital. When about to build, choice of situation is the first thing to be considered. For dwelling-houses, a spot should be chosen sufficiently elevated to be free from damps and noxious vapours, and, at the same time, sheltered from the severity of the winter: the neighbourhood of fens and stagnant waters should, if possible, be avoided. It should, however, be a spot where water can be easily procured; where drains may be made with facility; and where the principal apartments may have the advantages of southern and western aspects. The nature of the soil should be likewise carefully examined, by boring or sinking wells, in order to determine if a firm foundation can be had. The situation being chosen, attention to the various arrangements of the edifice becomes the next point of consideration. Drawings should be prepared, exhibiting every part correctly in plan, elevation, and section; and if it be a considerable building, a model also. The principal difficulty in architecture appears to consist in properly combining utility with ornament. Of course in buildings solely designed for ornament, as columns, obelisks, triumphal arches, &c. beauty alone should be regarded. On the other hand, in buildings solely intended for utility, every part ought to correspond with that intention. The least deviation from use, though contributing to ornament, is improper, and very disagreeable to persons of correct taste. The construction of the drains to carry off the rain and waste water should be the first proceeding; next, the foundation for the walls, in which the utmost care is requisite that the floor on which they are made to rest should be perfectly level and solid. When the board plat is laid, the first course of brick or stone should be laid without mortar, for lime disposes wood to rot, that in some soils would last for ages. After this, all the courses should follow with the same evenness and regularity. The thickness of foundations in

general ought to be double that of the walls which they have to support. The looser the ground, the thicker the foundation wall ought to be; which may be diminished as it rises, as well as the wall that is raised above it, which diminishes the expense without reducing the strength. The doors and windows should be proportioned to the magnitude of the building. The doors of dwelling-houses are usually from 7 to 8 feet high, and from 3 to 4 feet wide. Builders consider the proportion of three to seven in small, and one to two in large doors, to be the most eligible. With regard to windows, their number and size should be so arranged as to admit neither more nor less light than may be requisite. Their width in all the storeys should be the same; but the different heights of the rooms make it desirable to vary their height also; but in this much must depend upon the reigning taste or fashion. The windows in all the stories of the same aspect must be placed exactly over one another. The mathematical rule for apportioning light to rooms is as follows: multiply the length of the room by the breadth, and multiply the height by the product of the length and breadth, and out of that product extract the square root, which is the light required. For example: suppose a room to be 36 feet by 24, and 15 feet in height, the square root of the product of these numbers, when multiplied as described, will be 113 feet, which, divided into four parts, will give 28 feet 3 inches to each window. A good proportion for this area is 8 feet 6 by 3 feet 4, and so for any others by the same rules of proportion. For the construction and proportions of chimneys, see CHIMNEY. The simplest form of a roof that will resist the influence of the weather is the inclined plane; yet, independently of its want of symmetry, it does not admit of the greatest strength from a given quantity of timber. The best figure is that which consists of two inclined planes, meeting at the top over the middle of the building in a ridge or horizontal line. High pitched roofs being most suitable to the pointed architecture, were introduced at the same time, and form one of the most striking features of the Gothic style. This equilateral triangular roof prevailed in private as well as public buildings till the introduction of the Roman style by the celebrated Inigo Jones, and the consequent expulsion of the Gothic architecture. The chief advantages of high pitched roofs are, that they throw off the rain and snow more quickly; they may be covered with smaller slates, and are not so liable to be injured by heavy winds; while low roofs, as they require shorter timbers, are much cheaper, and have less pressure upon the walls. When executed with judgment, the roof is one of the principal ties to a building, as it connects the external walls, binds the whole into one mass, and preserves it from the injuries and decay which would soon be occasioned by rain and frost. Trusses are strong frames of carpentry, so contrived as to act like a solid body, and support certain weights at given immovable points, the truss being suspended from two such immovable points; they are generally made of a triangular form, and placed at equal distances on the wall plates, in vertical parallel lines, at right angles to the walls. Some excellent examples of trussing, especially on the suspension principle, are given under the article BEAM. See also ROOF. Various methods are adopted for the construction of floors according to the different bearing of the timbers. In small rooms the floors consist in general of single joists, but in large rooms two rows of joists are employed, one supporting the other above, and fixed at one end into a beam called the girder, which is usually placed transversely in the middle of the space; if the size of the room requires three compartments of joisting, two girders will be needful. The upper row of joists is called bridging joists, and the lower, binding joists. Stairs are used as the means of communication to the different storeys of a house, and the space in which they are enclosed is called the staircase. The utmost attention on the part of the builder is necessary in fixing the staircase, and in determining all its just proportions. The steps, whether of marble, free-stone, or wood, &c., may be supported at both ends, or at one only; when the latter, it is usually the broadest, though in small wooden stairs the steps are sometimes made to project from a newel, to which the narrow ends are fixed. The height of large steps must never be less than 6, or more than 7½ inches. The breadth should not be less than 10, and never exceed 18

inches. The length of them cannot conveniently be less than 3 feet, or more than 12 feet. Geometrical stairs have their outer ends fixed in the wall, and the under edge of every step supported by the edge of the one below it. The upper part of the joint may be level from the face of the riser to about 1 inch within the joint; the plane of the tread of each step is thus continued about an inch within the surface of each riser; the lower part of the joint has a narrow surface perpendicular to the rake of the stair at the end next the newel. Geometrical stairs constructed of stone depend upon the following principle:—that every body must be supported by three points at least, placed out of a straight line; and consequently, if two edges of a body, in different directions, be secured, they will become relatively immovable; such is the case in a geometrical stair; one end of the step is always tailed into the wall, and one edge rests either on the ground, or on the edge of the inferior step or platform. The methods of forming staircases are so various that it would be impossible to give even an intelligible definition of them that would be compatible with our limits; we shall, therefore, at once refer the reader for information on this and all the other departments of this subject to *The New Practical Builder*, which unquestionably is the most complete modern work upon this important art, whether as respects the plainest or the most magnificent structures.

Building en Pisé. An extremely simple, durable, and economical method of building walls, in very general use in the neighbourhood of Lyons, and which has been introduced into this country. It consists simply in ramming earth firmly between moulds formed of boards set upon the ground-plan of the walls; and although it may seem that buildings erected upon this plan must resemble the mud cabins which disfigure many parts of this country, they nevertheless differ widely both in appearance and durability, since they may be made as neat as brick buildings, and equally durable, houses of 150 years standing, built in this manner, being by no means rare in France. The following instructions for this mode of building are taken from a paper in the *Transactions of the Society of Arts*, Vol. XXVII. by Mr. Salmon, who has practised it to some extent on the estate of the Duke of Bedford, at Woburn. The only tools necessary for building *en pisé*, besides the ordinary ones used in building, are the moulds and rammers. The mould consists of two side pieces, each composed of two planks 12 feet long, 10 inches wide, 1 inch thick, strengthened by several pieces of board nailed across them on the outside, at equal distances apart. Holes are made through these pieces of board at top and bottom, to receive iron bolts, which hold the two boards parallel to each other, 14 or 16 inches asunder, which is the thickness of the walls intended to be formed between them. The bolts have a large head at one end, and a key passes through the other to keep the planks together. Two boards, equal in length to the thickness of the wall, are placed between the planks at the ends to form the ends of the mould. The rammer consists of a short staff with an iron head, which should not be more than half an inch wide on the edge, in order that it may more forcibly compress the earth in every part, which a flat rammer could not do so well. In forming the angles of a building, four mould boards are requisite: each of the boards for the internal angle have two eye-bolts through, and the boards being set together at the proper angle, a bolt is passed through the four eye-bolt, forming a kind of hinge; the boards are retained in their position by an iron stay, hooked into a staple in each of the boards. The boards for the outer angle are connected by two short pieces of iron projecting from one of the boards which pass through corresponding holes in the sides of the other board near the end, and are keyed up on the outer side of the mould. The process is conducted as follows:—the foundations of the intended building must be laid of brick work, stone or rubble, and be carried at least 9 inches above the surface to protect the pisé from the rain; the mould frames are then set up on the foundation walls and bolted together, the thickness of the foundation regulating the distance at bottom, which distance is maintained at the upper part of the mould by pieces of wood cut to the proper length, which are laid upon the upper connecting bolts; head boards are also placed at each end to retain the earth. Loose earth is then thrown into the mould to the depth of

about 3 inches, which is afterwards drawn back, and cleared from the face of the mould, and the space filled up with a facing composition, forming, on an average, about an inch in thickness; the whole is then firmly rammed (on which, and properly preparing the facing stuff, the perfection of the work will greatly depend,) until it is quite hard, when it will be compressed to about 1½ inch in thickness. The common facing stuff is composed of lime, one part, and earth, the same as that used for walling, three parts. These are mixed together, and slaked the same as mortar, and the more it is wetted and slaked the better, provided time can be allowed for it to dry again and pulverize, so as to be fit for ramming. The better sort of facing stuff may have a small quantity more of lime in it. When by the repeated addition of layers of earth, well rammed down, as before described, the mould is filled, the keys are to be taken out of the bolts, and the bolts drawn out; the planks are then removed, and put together again another length along the wall; but the bolts at one end being put through the holes left in the wall, only one of the end boards is now required; the earth is then thrown in and rammed as before, and the process is continued until one course of all the walls is completed. When the lower course is finished, the mould is taken to pieces and put together upon that course, the lower bolts of the frame being put through the holes which the upper bolts made in the wall at the first operation; but in order that the vertical joints formed between each mould should not coincide in the several courses, the end board is in the first set of the moulds for a new course, set at the middle of the length of the moulds, so that the work shall form a break-joint, as it is termed in brick-work, with the course below. Windows and doors may be left in the walls by fixing the heads of the moulds, and carrying up quoins to form the same; in erecting which some bond timber should be laid in coarse mortar, and rammed in with the earth; lintels may also be laid at the proper height. This method is the cheapest where only one window or door of a size is wanted; but if many are required, the readiest way would be to make some rough frames of boards, of equal width to the thickness of the walls, and place them in the situations of the windows and doors. When done, the earth is rammed up to them, laying bond timber on the sides, and lintels over them. In both cases the windows and door frames are to be put in their places, and fastened to the bond timber after the walls are up. The bond timber, lintels, and plates, should be kept as thin as possible in order to prevent any disagreement between the earth and timber in the shrinking or drying of the same. The bond timbers may be 4 inches by 1½; floor or wall plates 6 inches by 2; lintels about 4 inches thick. For common cottages, when the whole of the walls are up and covered in, the holes should be stopped with very coarse mortar, made the same as the facing stuff, but used wetter, and after standing some time to become thoroughly dry, may be either lime washed or finished with rough cast; but if it be required to make the finishing as perfect as possible, the following is the best mode; viz. with water and a brush thoroughly wet and soak the wall for two or three yards, in superficies, at a time; all which parts, during the said wetting, should be worked about with a hand float until the face be rubbed smooth and even, by which the facing composition will so wash up as to become a pleasant regular colour, the face smooth and hard when dry, and not liable to scale off as a coat of plastering would do. It should have been mentioned before, that, as it frequently happens that the top of one course becomes too dry to attach to the succeeding course, it is advisable that, as soon as the frame is set for the succeeding course, a small quantity of thick grout, composed of $\frac{1}{5}$ lime and $\frac{4}{5}$ earth, be poured on the top of each course immediately before the first layer of earth is put in. A very small quantity is sufficient, and will add much to the strength of the work by cementing the courses well together at the joints. The workman should also, with the corner of his rammer, in ramming home to the upright joints, cut down a little of that part of the wall up to which he works: this will make the upright joints key together, and unite in a solid manner. The earth proper for this work should be neither sand nor clay singly, but a mixture of both. Clay is very objectionable, as is also chalk, or calcareous earth of any sort. Sand is also not

proper, unless accompanied by some binding property; the bolder and coarser the sort of earth the better. When used, it should retain no more moisture than just to make it adhere under the pressure of the thumb and finger. Where the earth is not by itself proper, it may generally be rendered so by admixture with either clay or with coarse sand, as the case may require. With respect to the expense of this sort of walls, Mr. Salmon observes that, as labour is the principal part of that expense, and as in some places labour is dearer than in other, the best mode of estimating it at different places is from the quantity that a man should do in a day, which he has found is 1¼ yard in the common day's labour of ten hours. At Woburn he estimated the expense as under:—

	£	s.	d.
Labour, to making facing composition, fitting in, and ramming to a 16-inch wall, when the earth is at hand, (labourers being at 1*s*. 10*d*. per day,) per yard superficial	0	2	2
Lime for facing composition, at 8*d*. per bushel	0	0	3
Lime and labour in facing the outside of wall	0	0	3
Total, if finished and faced on one side only	0	2	8
If faced and finished on both sides, add	0	0	8
Total expense for walls finished on both sides	0	3	4

At the same place, the value of a yard of brickwork is more than ten shillings, of walling only 14 inches thick, the bricks being forty-two shillings per 1000, and lime eightpence per bushel; consequently the economy of pisé must appear; and the same difference will be found in any other place where lime and bricks bear the same price, and proper earth can be found at hand. But it must not be concluded that the entire expense of a building will be in the same proportion; the economy of pisé over brickwork applies only to the walls of a building, the roof, floors, fittings, &c. will be nearly the same in both cases, and even as regards the walls, the brickwork of the foundations must be taken into the calculation.

BUOY. A floating mark to point out the position of objects beneath the water, as shoals, anchors, &c.; also any light body used to support in the water another body, whose specific gravity exceeds that of water, as the buoys used to support the swivel rings of mooring chains, &c. The buoys used to mark the position of shoals, and to point out the right channel, are generally large and strong conical casks, made water tight, and are retained in their proper situation by a rope from the apex, made fast to an anchor dropped in the desired spot. These buoys are variously distinguished, either by their colour, or numbers painted on them; also sometimes by small beacons rising from their upper surface. All these buoys are under the superintendence of the Corporation of the Trinity House. Ships' buoys are generally formed as double cones attached at their bases, and are mostly composed of wood; but these being very liable to sink by leakage, buoys made of plate iron have for some time past been extensively used both in the royal and mercantile navy. They are attached by ropes, termed buoy-ropes, to the anchor, care being taken that the length of the buoy-rope exceeds the depth of water in which the ship is to anchor. Their principal use is for weighing the anchor in cases where the cable has broken or been let go.

BUOY (*Life*). A buoy intended to support persons who have fallen into the water, until a boat can be dispatched to their assistance. The forms and materials of which life buoys are composed are very numerous. The annexed cut represents a very simple and effectual machine of this kind invented by Mr. Scheffer. *Fig.* 1 is the machine inflated with air. It is made of skins, without any seam, (by a process of which the inventor retains the secret,) and is perfectly air and water tight; it is provided with an ingeniously contrived stop-cock, which screws into the hole shown in the engraving, by means of which the machine may be readily inflated by blowing with the mouth, and its escape afterwards rendered impossible. The buoyancy of the machine is suffi

cient to support two persons; so that a man equipped with one, even if totally unacquainted with swimming, need not hesitate to proceed to the assistance of a person struggling in the water; and it is put on in a moment, by merely stepping into it, and passing it up to the chest, where it may be worn without

Fig. 1.

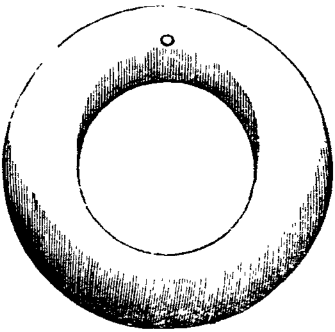
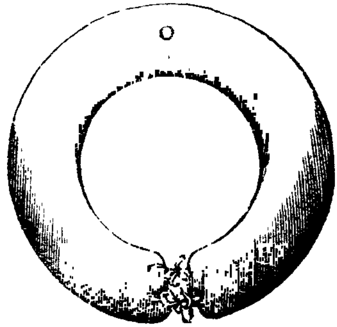
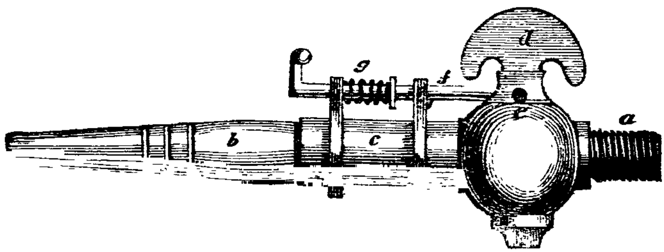


Fig. 2.

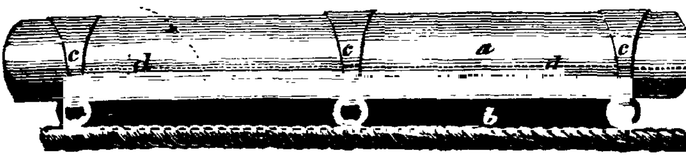


inconvenience, or in the least impeding the full action of the limbs. *Fig.* 2 represents another construction, by which the machine can be more easily put on over the clothes. The following cut represents the air cock. *a* is the nozzle



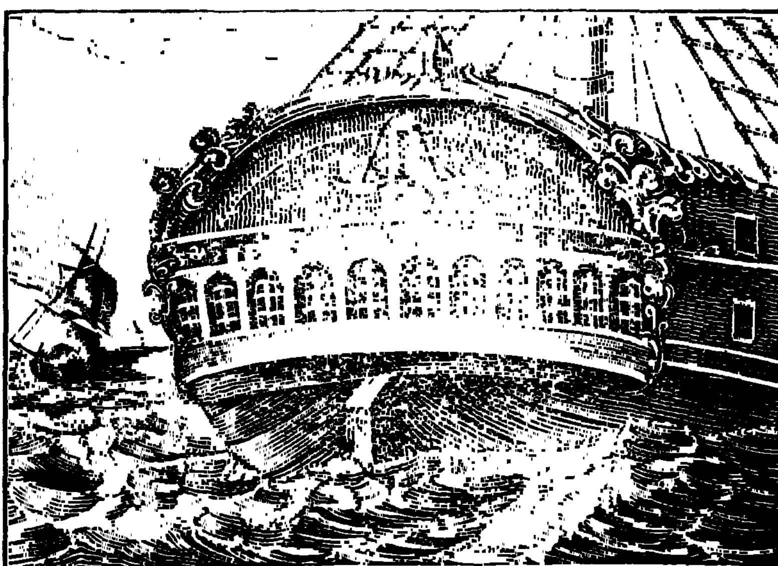
of the cock, which is screwed into the elastic air vessel; *b* an ivory pipe screwed into the barrel, used, when required, as a mouth-piece to inflate the vessel; when that is effected, the handle *d* of the plug is turned, so that the hole *e* of the plug is brought round opposite to the bolt *f*, when the spiral spring *g* projects the bolt into *e*, and locks it fast. The hole *e* is perforated through the plug, so that the locking takes place whether the plug be turned to the right or to the left: thus the cock is secured from being opened by accident, and the escape of the air is prevented. To open the air passage it is necessary to draw and hold back the spring-bolt with one hand, while the other turns the handle *d* into the position shown. Another important purpose to which these buoys may be applied is that of floating a rope from a stranded ship, by which means a communication with the shore is more easily established than when it is attempted to convey a rope from the shore to the ship, as the wind and sea assist in the transmission of the rope in the first case, whilst in the latter, they form a serious obstacle to it. Spars and casks are sometimes employed to float the rope, but are much inferior to the present invention, as the lives of the men passing along the floating line are greatly endangered by their being struck with them. The weight of such apparatus likewise keeps the floats deep in the water, consequently less exposed to the action of the wind, so that the tide may carry the rope in a wrong direction; but with Scheffer's buoyant vessels lying on the surface of the sea, the wind would have so powerful an effect as to render the

course of the tide immaterial; the passengers and crew might then with security pass along the rope to the shore. *a* the air vessel, or float for the rope *b*,



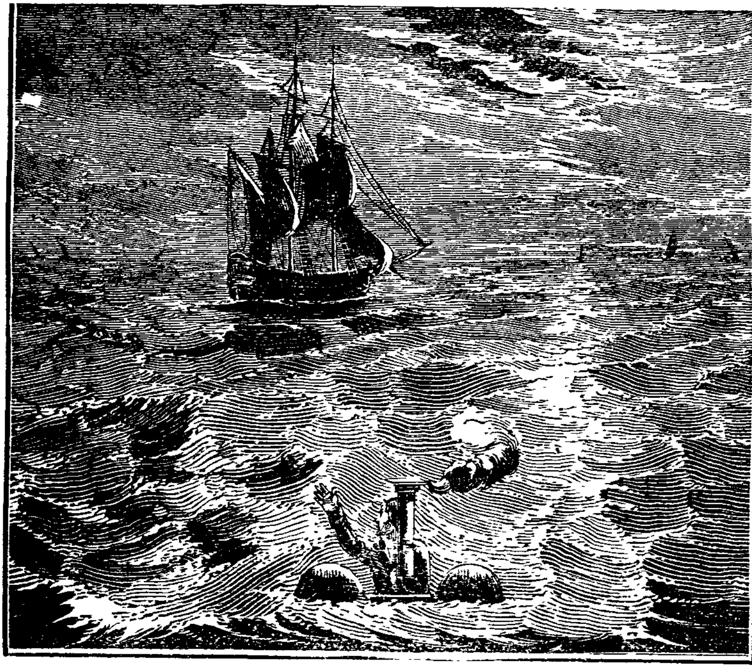
which is suspended by the rings to the bands *c c c; d d* the water line, or depth at which it lies immersed when the rope is attached.

A most admirable life buoy, for the preservation of men who may have the misfortune to fall overboard at sea, by day or night, has been invented by Lieut. Cook, R.N. and is so much approved, that the lords of the Admiralty have given orders that every ship in the royal navy shall be fitted with one. The buoy is so fitted to the stern or quarter of the ship, that in the event of an accident by night, it can be detached from its position into the water in about ten seconds, with a fusee at the head of the staff, giving a brilliant light, which a sea passing over it cannot extinguish. Ships may on these occasions frequently have to run a mile before they can sufficiently shorten sail so as to heave to with safety; but the buoy having fallen close to the man, the light blazing above his head will direct the boat to the spot without loss of time: this is a most valuable feature in the invention, invaluable, as from the great difficulty of finding a man in the water in a dark night, under these circumstances, men have been left to perish when there has been every reason to conclude that they had reached whatever might have been thrown to their assistance. The apparatus consists of two hollow copper spheres, connected together by a horizontal bar, through the middle of which is fixed, vertically, a strong staff, formed of a metallic tube;



the upper extremity of this tube supports the fusee, and the lower portion contains the balance rod and weight, which drop out of the tube when the apparatus is released from the ship, and preserves it upright in the water; the fusee is lighted at the same instant by a gun lock. The above cut represents

the life buoy suspended at the stem of a vessel. In many ships, the communication with the triggers for firing and for letting it go, is so contrived, that the man at the helm can detach it without quitting his post. The following cut



represents the life buoy in use, with the fusee blazing over the head of the man, who is seen standing on the balance plate.

BURNING GLASS and BURNING MIRROR. Instruments for concentrating upon a very small surface the rays of the sun, which fall upon a much more extended one, by which means such an intense heat may be produced as to fuse, burn, or volatilize most substances. Burning glasses are convex lenses, which, acting according to the laws of refraction, transmit the rays, but incline or refract them towards a common point in the axis, called the focus. These were not entirely unknown to the ancients, although we have no minute accounts of their construction or performances; but in modern times very powerful instruments of this description have been constructed. The most celebrated is that made by Mr. Parker, of Fleet-street, at an expense of 700*l.*, and several years of labour and research. It consisted of a lens composed of flint glass, which, when fixed in its frame, exposed a surface of 32 inches diameter in the clear; the distance of the focus was 6 feet 8 inches, and its diameter one inch. The rays from this large lens were received and transmitted through a smaller one, of 13 inches diameter in the clear within the frame, its focal length 29 inches, and the diameter of the focus $\frac{3}{8}$ of an inch. Amongst other remarkable effects produced by this instrument were the following: 3 grains of cast iron were fused in ten seconds; 20 grains of gold in four seconds; 10 grains of steel in twelve seconds; and 10 grains of common limestone in fifty-five seconds. Ten cut garnets, taken from a bracelet, began to run the one into the other in a few seconds, and at length formed into one globular garnet. The clay used by Mr. Wedgwood, to make his pyrometric test, run, in a few seconds, into a white enamel. We are sorry to add to the account of this

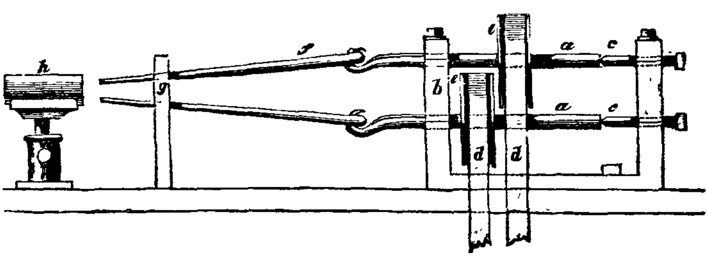
wonderful instrument, that, after being offered for sale to several learned societies, we believe it was sent to China, either on speculation, or amongst the presents which accompanied Lord Macartney's embassy, and was there left.

Burning mirrors are concave mirrors or reflectors, formed of polished metal or silvered glass, and which, acting by the laws of reflection, throw the rays back into a point or focus before the glass. These instruments were not only well known to the ancients, but, if we may credit the accounts which have come down to us, the effects of some of their contrivances were superior to any produced in modern times by the same means. Archimedes, it is said, reduced the Roman fleet under Marcellus to ashes, by burning mirrors, at a bowshot distance; and Proclus is said to have burned the fleet of Vitellius at the siege of Byzantium by the same means. Of the moderns, the most remarkable burning mirrors are those of M. de Villette, and of Buffon. That of M. de Villette was 3 feet 11 inches diameter, and its focal distance 3 feet 2 inches. It was composed of tin, copper, and tin glass. Some of its effects, as found by Dr. Harris and Dr. Desaguliers, are, that a silver sixpence melted in $7\frac{1}{2}$ minutes; a halfpenny melted in 16 minutes, and ran in 34 minutes, and a diamond weighing 4 grains lost $\frac{7}{8}$ of its weight. That of M. Buffon is a polyhedron, 6 feet broad, and as many high, consisting of 168 small mirrors, or flat pieces of looking glass, each 6 inches square, by means of which, with the faint rays of the sun, in the month of March, he set on fire boards of beech wood at 150 feet distance. At another time he burned wood at 200 feet distance; he also melted tin and lead at the distance of above 120 feet, and silver at 50 feet.

BUTTON. A fastening for various parts of dress. Buttons may be divided into two general classes,—those with shanks, or loops of metal, for the purpose of attaching them to garments, and those without shanks; and each class is manufactured from a great variety of materials, and by a variety of methods. Of buttons with shanks the greater number are composed of metal, although glass and mother of pearl are also employed for the purpose. Metal buttons are formed in two different ways, the blanks or bases of the buttons being either cast in a mould, or stamped out of a sheet of metal; the former method is generally employed for making white metal buttons, and the latter for plated and gilt buttons. To cast buttons, a great number of impressions of the pattern of the button are taken in sand, and in the centre of each impression is inserted a shank, the ends of which project a little above the surface of the sand, and fused metal is poured over the mould. When cool, the buttons are taken from the moulds, and after being cleansed from sand by brushing, are placed in lathes, the edges are turned, the face and back smoothed, and the projecting part of the shank also turned. The buttons are then polished by rubbing the faces upon a board spread with rotten stone of different degrees of fineness, and afterwards by being held against a revolving board covered with leather, upon which is spread a very fine powder of the same materials; finally, they are arranged on a sieve or grating of wire, and immersed in a boiling solution of granulated tin and cream of tartar, by which means their surfaces become covered with a thin layer or wash of the metal, which improves their whiteness without injuring their polish. The blanks of plated buttons are cut by a fly-press out of copper plate, coated on one side with silver. They are then annealed in a furnace, and afterwards stamped by the descent of a weight, as in a pile-driving machine, the die being fixed in the lower surface of the weight. The soldering of the shank is performed on each button separately, by the flame of a lamp and a blow-pipe: the edges of plain buttons are next filed smooth in a lathe, and the buttons are afterwards boiled in a solution of cream of tartar and silver; they are then placed in a lathe, and the backs brushed, and afterwards burnished with blood-stone. The metal used for gilt buttons is an alloy of copper and zinc. This metal is rolled out into sheets, and the blanks stamped out, which are then planished if intended for plain buttons, but if for figured buttons, the impression is now given The shanks are next attached, which is effected as follows: each blank is furnished with a pair of small spring tweezers, which hold the shank down upon it on the proper place, and a small quantity of solder and

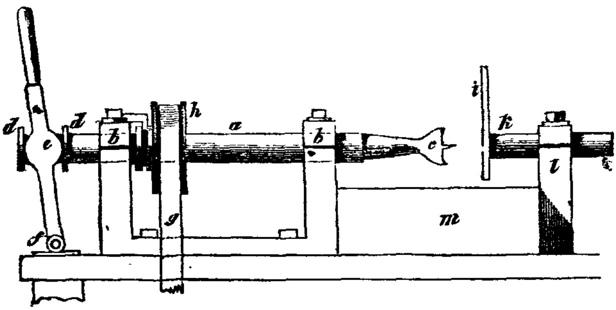
resin is applied to each. They are then exposed upon an iron plate to a heat sufficient to melt the solder, by which the shank becomes fixed to the button; and whilst still warm they are plunged into nitric acid, to remove the oxide formed on the surface by the heat employed in soldering the shanks. They are then placed in a lathe, the edges rounded, and the surfaces rough burnished, which renders them ready for gilding. Five grains of gold are fixed by Act of Parliament as the least quantity to be employed in gilding a gross of buttons of 1 inch in diameter. An amalgam is formed of gold and mercury, and the buttons are placed in an earthen vessel along with the amalgam, together with as much aquafortis as will moisten the whole, and the mixture is stirred with a brush until the buttons are completely whitened. To dissipate the quicksilver the buttons are shaken in an iron pan, placed over a fire, until the quicksilver begins to melt, when they are thrown into a felt cap and stirred with a brush, to spread the amalgam equally over their surfaces; after which, they are returned to the pan, and the mercury volatilized completely by the increased heat, leaving the gold evenly spread in a thin film over the surface of the buttons; they are then burnished in a lathe, which completes the operation. The better sort of buttons undergo the gilding process twice or thrice, and are distinguished accordingly as "double" or "treble gilt." Glass buttons are formed of glass compressed, while in the fluid state, in moulds, in which the shank is inserted, and when the glass becomes cold, the shank is firmly retained in its place. In mother-of-pearl buttons the method of inserting the shank is extremely ingenious: a hole is drilled at the back and undercut, that is, larger at the bottom than at top, and the shank being driven in by a steady stroke, its extremity expands; on striking against the bottom of the hole, it becomes firmly rivetted into the button, forming a kind of dove-tail joint.

Buttons without shanks are of two kinds; the first are simply discs of horn, bone, wood, or other material, with four holes drilled through the face, for the purpose of sewing them to the garment. Horn buttons of this description are made from cow-hoofs by pressing them into heated moulds. The hoofs having been boiled in water until they are soft, are first cut into plates of the requisite thickness, and after into squares of the size of the diameter of the button, and afterwards reduced to an octagonal form by cutting off the corners. They are then dyed black by immersing them in a cauldron of logwood and copperas mixed. A quantity of moulds somewhat resembling bullet moulds, and each furnished with a number of steel dies, are then heated a little above the point of boiling water, and one of the octagonal pieces of horn is placed between each pair of dies, and the mould being shut is compressed in a small screw press, and in a few minutes, the horn becoming softened by the heat, receives the impression of the die, after which the edges are clipped off by shears, and then rounded in a lathe. The holes in buttons of this description are drilled by means of a lathe, represented in the annexed engraving. Four spindles, of which



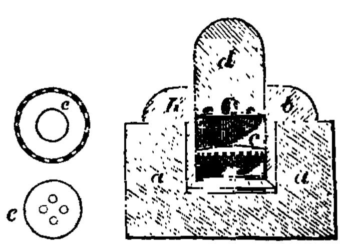
two only *a a* can be seen, are supported in bearings at *b*, and by the centre points *c c* are made to revolve with great velocity by means of two bands *d d* passing over pulleys *e e* fixed upon each of the spindles, each band driving two spindles, and receiving motion from a wheel worked by a treadle. At the end

of each of the spindles *a*, is a hook uniting them to four other spindles *f f* by similar hooks at one end, the other end of the spindles passing through four small holes in the plate *g*, and the projecting points being formed into small drills. The button is placed in a concave rest *h*, and pushed forward against the drills by a piece of wood. The standard *g* can be exchanged for another with holes more or less apart, and the rest *h* can be set at any height to suit different sized buttons. As the spindle holes in the plate *g* are nearer together than the holes in the standard *b*, the spindles *f f* converge; the hooks in the spindles are therefore necessary to form a universal joint. The second description of buttons without shanks consists of thin discs of wood or bone called moulds, covered with silk, cloth, or other similar materials. The bone for the moulds is made from refuse chips of bone sawn into thin flakes, and brought into a circular form by two operations, illustrated by the accompanying engraving. On one end of the spindle *a*, which revolves in bearings at *b b*, is



screwed a tool *c*, and on the other are two collars *d d*, between which a forked lever *e* embraces the shaft, the fulcrum of which is at *f*. The spindle *a* is put in rapid motion by a band *g* passing over the pulley *h*, and over a band wheel worked by a treadle; and the workman, holding the material *i* for the mould in his right hand, against a piece of wood *k* firmly held down in the iron standard *l* by two screws, by means of the lever held in his left hand, he advances the tool *c* against the material *i* of the mould; the central pin of the tool drills a hole through the centre of the intended mould, whilst the other two points describe a deep circle cutting half through the thickness of the material, and the flat surface is cut smooth by the intermediate parts of the tool. The tool is then drawn back a little by the lever *e*, and the material shifted to bring a fresh portion of the surface opposite the tool, and when as many moulds as the plate of the material will afford, are thus half cut through, the other side is presented to the tool, and the central point of it being inserted in the hole made in the first part of the operation, the other two teeth cut another deep circle exactly opposite the former one through the remaining substance of the material, and the mould is left sticking on the tool; by drawing back the lever *e* the tool recedes, and the mould, meeting a fixed iron plate, is pushed off the tool, and falls into a small box *m*.

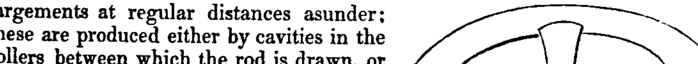
Covered buttons having come into very general use, various improvements have been introduced in the manufacture of them, and patents for this purpose have been granted to various parties, as Sanders, Needham, Aingworth, Church, and others. The following is Mr. Sanders' method of making covered buttons: a piece of the material with which the mould is to be covered is cut of a circular shape, somewhat larger than the intended button; upon this is placed a disc of card of the exact size of the button, and next a disc of paper coated with an adhesive composition, which will become soft and sticky by heat;



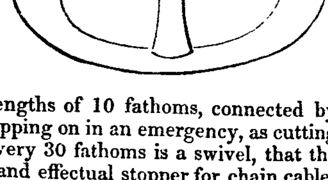
and upon these is laid a button mould *e* having four holes, through which threads or strings have been passed to form the flexible shank. These circular discs being put together, are then laid over a cylindrical hole in a metal block *a*; this hole being exactly the size of the intended button, and the covering of the button being larger than the hole, when the discs are pushed down into the hole, the material of the covering will wrinkle up on the edges round the other discs. The tube *b b* is then introduced into the cylindrical hole, and its lower edge being bevilled inwards, will, as it is pressed down, gather the plates of the cloth on the edge of the button; towards the centre is a metal ring or collar *c*, having teeth round its edge; somewhat like a crown saw is now passed down the tube *b*, and driven with considerable force by the punch *d*, and the block *a* having been previously heated, the adhesive matter will be softened, and cause the several discs to stick together, which, when taken out and become cold, will be very firm and retain its shape.

C.

CABLE. A rope of large diameter, by which ships are held to their anchors or moorings. The materials of which cables are formed are very various, as bass, hemp, sunn, and coir, or the husk of the cocoa nut, and latterly iron chains, of a particular construction, have been extensively used, and are commonly called chain cables. Cables are composed of either three or four ropes twisted together, each rope consisting of either three or four strands, each strand containing an equal number of yarns, which number depends upon the diameter of the cable. Cables are denominated by their circumference in inches, as a 22-inch cable, meaning a cable 22 inches in circumference. The length of all cables is the same, viz. 120 fathoms. The larger class of ships in the navy and in the East India Company's service are usually provided with the following cables: viz. two spliced together, for the best bower anchor; two for the small bower anchor; two for the sheet; one spare cable; and one cable for the stream anchor. The chains employed for cables have a short stay bar in the middle of each link, to prevent the sides collapsing when the cable is exposed to a heavy strain. The form of the links and stays, and the mode of applying the latter, have formed the subjects of numerous patents. The annexed figures represent one of the links of Mr. Hawks's "Patent Chains for Cables and Hawsers," and also illustrates the method of forming them. The novelty

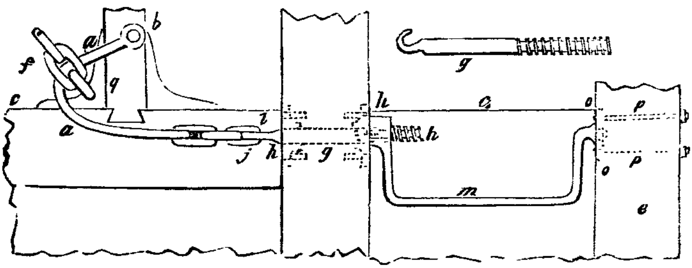


in the form of these links consists in their being thicker at the bends than at the sides; whereas in most other chain cables the links are either the same thickness throughout, or are smallest at the bends. The iron rod *a a* of which the link is formed, it will be seen has bulbous enlargements at regular distances asunder; these are produced either by cavities in the rollers between which the rod is drawn, or by swaging or forging. The rods being cut into exact lengths, they are turned round into links, and the ends welded together, when the bulbs should be situated exactly at the ends, as represented by the annexed figure at *a a*, and the stay-bar *b* inserted.



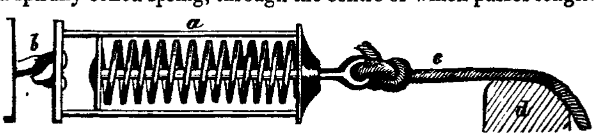
Chains for cables are commonly made in lengths of 10 fathoms, connected by a bolt and shackle, for the convenience of slipping on in an emergency, as cutting is of course out of the question; and at every 30 fathoms is a swivel, that the chain may not become twisted. A simple and effectual stopper for chain cables is much wanted, as considerable difficulty is frequently experienced in "bringing a ship up," as it is termed, when it blows hard. The ordinary stopper consists of two concave plates of iron, between which the chain passes; the lower plate

is firmly secured to the deck, and the upper plate turns upon a hinge. A long iron bar is inserted into a socket cast upon the upper plate, and to the outer end of the bar is attached a tackle, hooked to a bolt in the deck; and a number of men being stationed at the tackle, by hauling upon it they compress the cable so tightly between the plates, as to prevent the cable running out, or, by slacking it, allow it to run freely. This apparatus frequently gives way, and occasions serious damage. The following substitute, invented by Lieut. Kooystra, R.N., has been approved by the Society of Arts, who have presented the inventor with the silver Vulcan medal. The figure represents an under-view of the part of the deck where the stopper *a a* is fixed; this stopper is formed of an iron hook or clip, turning upon a bolt at *b*, and has a few links of chain at the other end; *d* and *e* are portions of two beams; *f* part of the chain



cable, held fast by the stopper; *g* a square bar, sliding through the beam *d*, and through square holes in the metal facing plates *h h;* *i* the hook in the end of the bar *g*, which takes the link *j* of the stopper; *k* a double-threaded screw, on the other end of the bar *g;* *l* the screwed end of a crank handle *m*, fitted on the screw *k;* the other end turns freely in the plate *o o;* *p p* the bolts which secure this plate to the beam *e*. By turning the crank one way, it will be seen that the cable will be tightly pressed by the stopper against the iron knee *q*, and by turning it the other way the pressure is relaxed. The sliding bar *g* is shown separate above.

Mr. William Shelton Burnett had a patent for a cable-stopper, of which the following is a description. This apparatus consists of a metallic box *a*, containing a spirally coiled spring, through the centre of which passes longitudinally

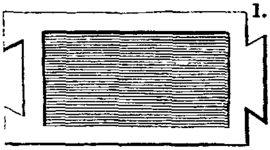


a bar; one end of this is strongly rivetted to an iron plate, and the other terminates in a large eye, for the reception of a hook or a rope. Now, supposing the cylinder *a* to be made fast at *b* to some staple part of a ship, and the cable *c*, which passes over the side of a ship *d*, to have an anchor attached to the other extremity, when any strain comes upon it, the bar is drawn more or less out of the cylinder, compressing the spring, thus affording an elastic resistance, which, continually increasing with the force applied, will prevent those accidents of tearing away the fastenings, which might, without such apparatus, be the result. It is of course that this contrivance is equally applicable to any other tackle, which it will always keep in a proper state of tension after the cause of the adventitious strain has ceased to operate.

CACAO NUT, or Cocoa. An oblong roundish nut, nearly the shape of an almond, but larger; the shell dark-coloured, brittle, and thin; the kernel both externally and internally brownish. It is the produce of a small tree, the *Obrama Cacao*, bearing a large fruit like a cucumber, which contains thirty or

more of these nuts. Chocolate is prepared from these nuts. A patent was lately obtained for a preparation of cocoa, called "Marshall's Extract of Cocoa." The specification, which is dated the 10th February, 1830, describes the process to consist in boiling, for an hour, a pound of powdered cocoa in a gallon of water; the mixture is then to be passed through a sieve, and the oily matter to be skimmed from the surface. It is next to be evaporated in a water bath, till it assumes the consistence of treacle, when it is to be preserved for use in bottles well corked and sealed, so as to render them impervious to the air.

CAISSON. A kind of chest-framed or flat-bottomed boat, sometimes used in laying the piers of bridges in deep or rapid rivers. The caissons for this purpose consist of a very strong platform of timber, to which are attached the two sides, in such a manner as to admit of their removal when no longer required. These sides, which are also very strongly framed of timber, to resist the great pressure of the water, are curved towards their extremities, so as to meet each other, and form a salient angle up and down the stream, and inclosing a space somewhat wider than the foundation of the pier of the bridge. The site of the pier being levelled by dredging or otherwise, the caisson is brought over the spot, and moored in the proper position; two or three of the lower courses of masonry are then built upon the platform of the caisson, and the water is then slowly admitted by a sluice in the caisson, so as to cause the caisson to settle into its place; and to prevent the effects of too great a pressure of water when the rise and fall of the tide is considerable, the water is generally admitted some time before high water, and pumped out again after the ebb tide has commenced, so that the workmen may resume their labours before low water. When the masonry is brought up as high as the level of the water, the sides of the caisson are detached from the bottom, and removed. Westminster and Blackfriars bridges were built on caissons, but the preference is now generally given to coffer dams. A patent was obtained by Mr. Deeble, for constructing jetties, piers, quays, &c. by means of what he terms "metallic caissons," or a peculiar description of cast iron boxes, variously combined by dovetails; these boxes, when fixed in their places to form a pier, or quay, &c. are filled with liquid lime and rubble, which soon sets hard, and forms a solid mass girt with metal. For the better elucidation of the plan, a few of the more simple forms of caissons, and their mode of uniting, as exemplified in the construction of a pier, are engraved herewith. The caisson is open generally both at top and bottom; the thickness of the sides proportioned to the strength and gravity required. It is proposed that each caisson be 7 feet in length, 5 feet in height, and from 2 to 5 feet in width, according to the nature of the work in which it is to be used. Caissons constituting foundations should be closed at bottom, and in raising one tier above another, each layer would become united to those immediately above and below it, by commencing the alternate vertical courses with a half caisson. *Fig.* 1 is the plain oblong square, with dovetails at the ends, only applicable to straight lines, either in banking exposed to the water, or to the interior of heavy works, as cross forts, or in bracings and buttresses to be



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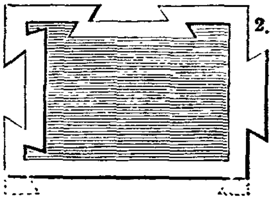

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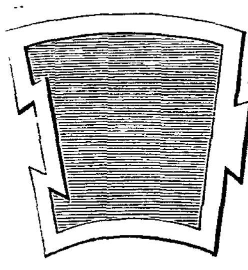

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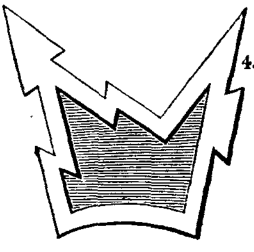
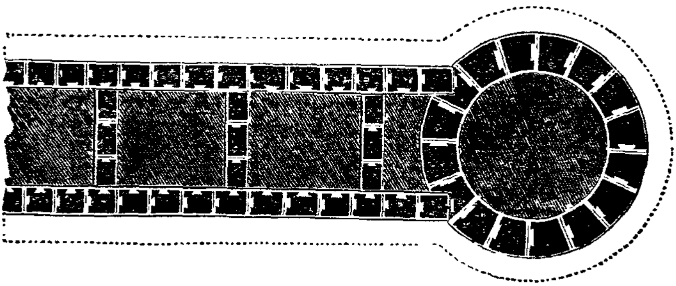


4.

buried in the earth. This form admits but little variation in its application, and none in its strength or gravity beyond what may be gained by increasing the thickness of its sides. *Fig.* 2 is the most universal form; it may be multiplied to any extent, yet is perfect in itself, requiring no change of form on the side to finish a work, and the ends may be conveniently completed by filling up the dovetail groove with a portable half dovetail. *Fig.* 3 is the radiated form, which may be used in a waved line along the coast, where great strength is required; it also applies to piers and bastions. The dotted projection is the half dovetail, which would be required to attach it to the cross fort; or the radiated caisson, should it be considered necessary to add another waved line, would give the effect of arch and counterarch. *Fig.* 4 is a radiated caisson, having extra dovetails for uniting the main line to the bastion. Any angle may thus be gained, simply by mooring this caisson in the bastion, in the direction required. *Fig.* 5 is the termination of a pier with a bastion: the external dotted

Fig. 5.



line shows the boundary of the sloped bank; the cross forts are introduced at suitable distances to insure great stability; and the inner dovetailed grooves being left in the inner lines, will enable the engineer to add cross forts and buttresses to any extent that may be required.

CALAMINE. An ore of zinc, principally used in making brass.

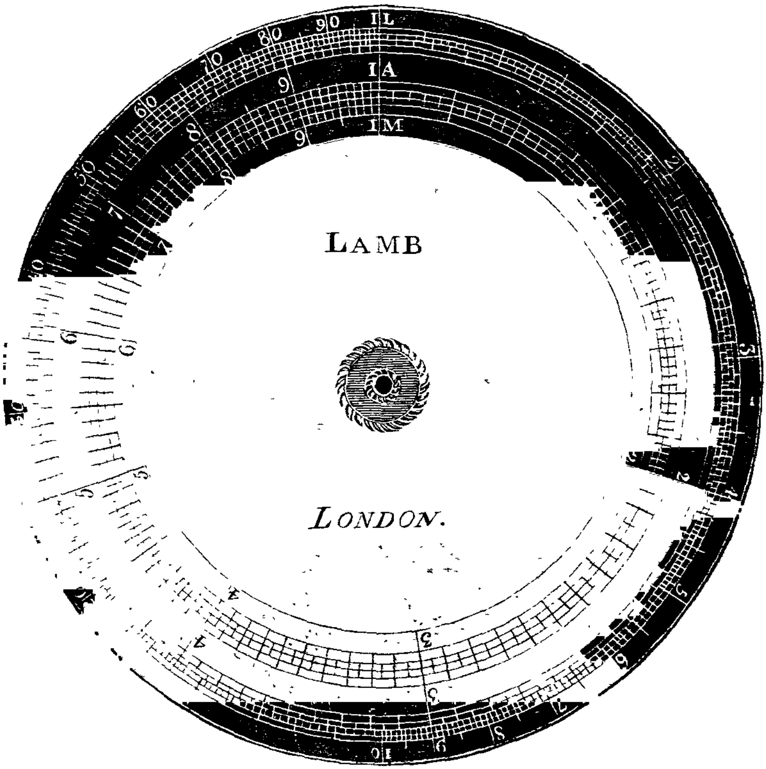
CALCINATION. The process by which some bodies are rendered reducible to powder; it consists in exposing the substances to a strong heat, so as to dissipate the water of crystallization and other volatile portions.

CALCULATING MACHINES. Machines devised for facilitating arithmetical computations. From a remote period of antiquity, various mechanical devices were resorted to for this purpose. Amongst the Greeks and Romans, an instrument called "abacus" was employed, consisting of a number of parallel threads, upon which were strung a number of beads for counters, to represent units, tens, hundreds, &c. The Chinese at the present day use in their computations an instrument called a swanpan, nearly resembling the Greek abacus, and which may now be met with in the toy-shops of London. There are large and small swanpans; those for mercantile purposes consist of many rows of small balls strung on wires, containing fifteen balls on each, with space for their being moved up and down with ease. These rows of balls are divided by a cross bar of wood extending from side to side, leaving five balls above and ten below. Each ball of the upper row is of the value of the ten balls on the lower row, and by moving down to the bar one of the upper balls, the ten lower balls which had been moved up to the bar, are at liberty to represent any further sum until they have all again reached the bar, when a second ball is brought down from the upper row, and so on until the five balls are engaged, when their value is represented by one ball on the adjoining wire on the left hand, and so on to any amount. These instruments are universally employed throughout China for the purposes of computation; and so expert are the Chinese in the use of them, that few Europeans, with the assistance of pen and ink, can keep pace with them. The celebrated Napier, the inventor of

logarithms, contrived an instrument by which the operation of multiplication is much facilitated, the product of any single figure with the multiplicand being represented at once by a very simple mechanical operation. This instrument, which consisted of a number of detached rods, each bearing at the top some one unit with the products of the same, multiplied by the nine units ranged in a line beneath it, is commonly known by the name of Napier's rods or bones. But by far the most useful contrivance of this kind is the Gunter's scale, so named after the inventor, Mr. Edmund Gunter, an eminent English mathematician, who likewise was the author of several other very useful inventions. In the extent to which the Gunter's scale has been adopted, it rivals the Chinese swanpan, whilst its powers far exceed those of the latter instrument. It consists of a flat ruler of box wood, 2 feet long, having various lines laid down upon it, by means of which all the various problems relating to arithmetical trigonometry, and their depending sciences, may be performed by the extent of the compasses only. This will be best explained by a description of the line, called the line of number, or Gunter's line, which is adapted to the solution of arithmetical questions, and exhibiting a few practical examples. The line of numbers is the logarithmic scale of proportionals, which, being graduated upon the ruler, serves to solve problems in the same manner as logarithms do arithmetically. It is usually divided into 100 parts, every tenth of which is numbered, beginning with 1 and ending with 10; so that if the first great division stand for the $\frac{1}{10}$ of an integer, the next great division will stand for $\frac{2}{10}$, and the intermediate divisions will represent hundredths of an integer, whilst the large divisions beyond 10 will represent units; and if the first set of large divisions represent units, the subdivisions will represent tenths, whilst the second set of large divisions will represent tens, and the subdivisions units, and so on. The general rule for using this instrument is as follows: since all questions are reducible to proportions, if the compasses be extended from the first term to the third, the same extent will reach from the second to the fourth term. The following are a few examples of some of the uses of this line. 1. To find the product of any two numbers, as 4 and 8: extend the compasses from 1 to the multiplier 4, and the same extent applied the same way from 8, the multiplicand will reach the product 32. 2. To divide one number by another, as 36 by 4: extend the compasses from 4 to 1, and the same extent will reach from 9 to 36. 3. To find a fourth proportional to three given numbers, as 6, 8, 9: extend the compasses from 6 to 8, and this extent laid the same way from 9, will reach 12, the fourth proportional required. 4. To extract the square root of a number, say 25: bisect the distance between 1 on the scale and the point representing 25, then half this set off from 1 will give the point 5 = the root required. In the same manner the cube root, or the root of any higher power, may be found by dividing the distance on the line between 1 and the given number, into as many equal parts as the index of the power expresses, then one of those parts set from 1, will extend to the number representing the root required. A great improvement has been made in this instrument, by means of which compasses are rendered unnecessary. It consists in having two lines of numbers placed one over the other, one of which lines is engraved upon a slider moving in a groove, and is applied as follows: the first term of the proportional upon the slider being set against the third term upon the fixed scale, the second term of the proportion upon the slider will stand opposite the fourth term on the fixed scale. Instruments of this description, with scales suited to almost every branch of art in which calculation is required, are now common amongst intelligent workmen, and the scale of chemical equivalents, by which the labours of the chemist are so much facilitated, is constructed upon the same principle.

Mr. Lamb has recently arranged the logarithmic scale in a circular form, by which the portability of the instrument, and the facility of its application, is so much increased, that an instrument much smaller than the following representation of it, and which can be conveniently carried in the waistcoat pocket, contains divisions larger and easier to read than those usually placed on the 2-feet sliding rule. On the face of the instrument (which Mr. Lamb calls a circular proportioner,) are engraved one double and two single logarithmic

lines, in concentric circles. The middle circle, which is the moving piece, and is marked A, has both edges divided, for the convenience of acting with the inner or outer circles, which are marked M and L. The moving and inner circles A and M are both numbered 1, 2, 3, 4, 5, 6, 7, 8, and 9. The space



betwixt each numbered division is divided into 10, and those divisions read for a second figure. From 1 to 2 each of those divisions is subdivided into 5, standing for the even numbers in the third places of figures. From 2 to 5 each tenth division is halved for the 5, in the third place of figures. The spaces must be subdivided by estimation for the intermediate figures. The outer circle, marked L, has a double line of numbers; the first half circle numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, and the second half marked 10, 20, 30, 40, 50, 60, 70, 80, 90. The figures on A and M may either signify 1, 2, 3, &c., or 10, 20, 30, &c., or 100, 200, 300, &c., and as the figured divisions alter, so, of course, must the subdivisions; sometimes they stand for decimals. In passing unity to the right, the numbers will contain a figure more, and in passing to the left they will contain a figure less; the first significant figure in a decimal will vary in like manner. Two numbers in a proportion which have the same name must always be taken on the same circle. For multiplication, division, and common proportion, A must work with M; for the square root and duplicate proportion, A must work with L. In direct proportion, the first and second terms will stand together; but in indirect proportion, the second and third terms will stand together.

Various machines have likewise been contrived by Pascal and others, by which arithmetical calculations were made by means of trains of wheels and

similar arrangements; and the late Earl Stanhope invented a machine of this sort, by which he verified his calculations respecting the national debt. But none of these contrivances can bear a moment's comparison with the stupendous machine designed by Mr. Babbage, and now nearly completed, the functions of which are to embody in machinery the method of differences, which has never before been done. It consists of two parts,—a calculating, and a printing part, both of which are necessary to the fulfilment of the inventor's views; for the whole advantages would be lost if the computations made by the machine were copied by human hands, and transferred to type by the common process. The greater part of the calculating machinery, of which the drawings alone cover 400 square feet of surface, is already constructed, but less progress has been made in the printing part. The practical object of this machine is to compute and print a great variety and extent of astronomical and navigation tables, which could not otherwise be done but at an enormous expense, whilst it would be impossible to insure the same accuracy. It can also compute the powers and products of numbers, and integrate innumerable equations of finite differences; that is, when the equation of differences is given, the engine, after being properly set, will produce in a given time any distant term which may be required, or any succession of terms commencing at a distant point. In order to convey some idea of the powers of the machine, we may mention the effects produced by a small trial engine, constructed by the inventor, and by which he computed the following table from the formula x^2+x+41. The figures, as they were calculated by the machine, were not exhibited to the eye as in sliding rules and similar instruments, but were actually presented to it on two opposite sides of the machine, the number 383, for example, appearing in figures before the person employed in copying. The table is as follows:

41	131	383	797	1373
43	151	421	853	1447
47	173	461	911	1523
53	197	583	971	1601
61	223	547	1033	1681
71	251	593	1097	1763
83	281	641	1163	1847
97	313	691	1231	1933
113	347	743	1301	2021

Whilst the machine was occupied in calculating this table, a friend of the inventor undertook to write down the numbers as they appeared. At first he rather more than kept pace with the machine; but as soon as five figures appeared, the machine was at least equal in speed to the writer. At another trial, 32 numbers of the same table, containing 82 figures, were computed in 2 minutes 30 seconds, or 33 figures per minute. On a subsequent occasion it produced 44 figures per minute, and this rate of computation could be maintained for any length of time.

CALENDERING. The operation by which all accidental wrinkles and creases are removed from various kinds of cloths, and their surfaces rendered smooth and uniform previous to packing for transport: calicoes are likewise calendered before printing. The common calendering machine nearly resembles the ordinary mangle, but worked by a horse-wheel, on account of its greater dimensions and weight; but the more improved machines consist of a series of rollers, between which the cloth passes, the rollers being subjected to heavy pressure, and turning simultaneously either by simple contact, or by means of wheel work. Machines on this principle we believe are of foreign invention, but have received two important improvements in this country; first, by the introduction of tubular cast iron rollers, into which heaters can be inserted when requisite, which greatly assists the operation with some kind of goods; and secondly, in the substitution of rollers formed of pasteboard for wooden rollers, the former not being liable to crack or warp like the latter, and being susceptible also of an astonishing degree of polish. These paper or pasteboard rollers are formed as follows: the axis or shaft is formed of a square bar of wrought iron,

turned cylindrical at the bearings; a circular iron plate, of the exact size of the intended roller, is placed upon the square part of the shaft, and near to the end, and a great number of discs of pasteboard, somewhat larger than the intended roller, and having square holes in the centre, are next put upon the shaft, and then another iron plate, and the whole are screwed together by nuts at the ends of four long iron bolts extending from one iron plate to the other. In this manner a cylinder is formed, considerably longer than the intended cylinder; this is removed to a stove or hot room, and as the paper shrinks by the heat, the plates are gradually screwed up. When, at the end of some days, the paper ceases to shrink, the cylinder is removed from the stove, and becoming exposed to the humidity of the atmosphere, it has a tendency to expand, and becomes exceedingly dense and solid, and is completed by turning in a lathe to the intended size. Some goods are required to have a high polish, called glazing, upon one side; this glazing was formerly effected by rubbing the cloth with a smooth flint stone, but is now generally performed in the calendering machine, by an addition of wheels, which causes one of the rollers to move slower than the rest, and the cloth consequently rubbing over the polished surface of the

Fig. 2.

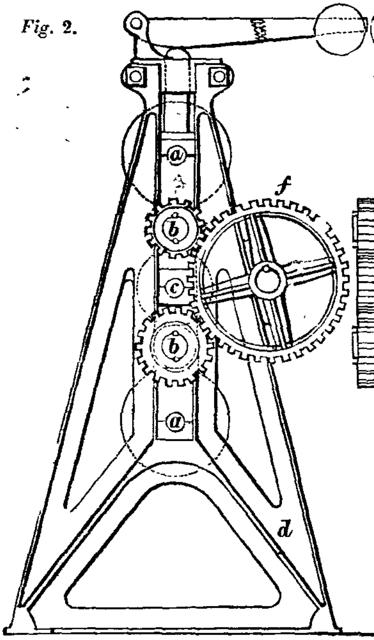
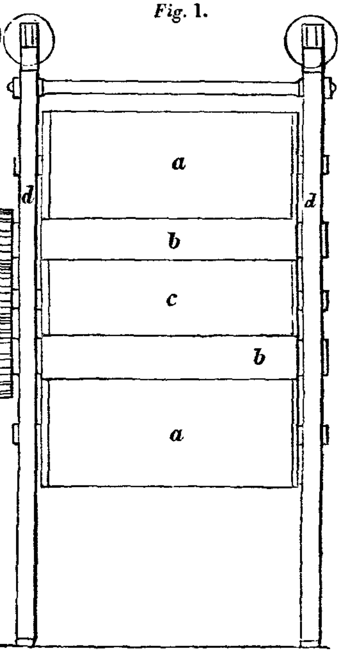


Fig. 1.

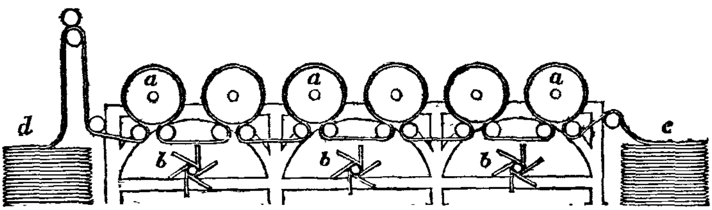


slowest mover, becomes glazed. *a a Fig.* 1, are two paper rollers, each of 20 inches diameter; *b b* two hollow cast iron cylinders, 8 inches diameter, and 2 inches thick, the exteriors of which are turned perfectly smooth; *c* a paper roller, 14 inches diameter; *d d* the framing of cast iron, containing the bushes or bearings, in which the journals of the rollers revolve; these are firmly pressed together whilst the cloth is passing through, by means of weighted levers. *Fig.* 2 is an end view of the same calender, with the wheels for glazing the cloth; the wheel on the upper cylinder *b* is 10 inches diameter, that on the under cylinder *b* is 13 inches diameter, and both are connected by the wheel *f*; so that the wheel on the under cylinder being nearly one-third more in diameter than that on the upper cylinder, the difference of their motions retards the

centre paper roller, by which means the upper cylinder passes over the cloth one-third quicker than the cloth passes through the calender, and polishes it in consequence. For dressing muslins, gauzes, and other light, transparent fabrics, a smaller species of calender is employed. It consists of only three cylinders, of equal diameters, (generally about 6 inches,) and is easily moved by a common winch or handle. The middle cylinder is of iron; they are all moved with equal velocities by small wheels. This machine is always used in a cold state. Calendering forms one part of the business of a packer; in the subsequent stages the goods are folded into certain forms, depending upon the nature of them, and the markets for which they are intended; they are then subjected to the action of a very powerful press, and whilst under pressure are corded, so that when removed from the press they occupy much less room than they otherwise would do.

CALICO PRINTING. The art of producing upon calico or cotton cloths patterns or designs combining a variety of colours, so as to produce an agreeable and pleasing effect. This ingenious business, as at present conducted, may be considered as one branch of the art of dyeing; and as it depends chiefly upon the proper application of a few compounds, called mordants, we shall commence our description of the process by explaining briefly the nature of colours, and the uses of mordants. The colouring substances employed in this art may be divided into two classes, viz. *substantive* and *adjective*. A *substantive* colour is one which of itself is capable of producing a permanent dye; such are woad and indigo, and the solutions of some metals, particularly those of iron, cobalt, gold, platinum, and silver, which give various colours, according to the processes by which they are prepared. By *adjective* colours are meant all those which are incapable of imparting permanent colours without the aid of certain intermedia, which having a greater affinity both for the colouring matter and for the cloth, than the colouring matter has for the cloth, forms, as it were, a bond of union between the two latter substances. These intermedia are called mordants: the principal ones at present in use in this country are the acetate of iron, the acetate of alumina, and the various solutions of tin. In the usual process of dyeing with adjective colours, the entire piece of cloth is steeped in the mordant, and some time afterwards is submitted to a bath of the particular kind of colouring matter which is to be imparted to it; but in printed goods, certain parts require to be left white, a pattern, therefore, of those parts which are to be coloured is cut in relief on blocks of wood, or plates of metal, and the mordant being applied over the whole surface of the pattern, the pattern is then impressed upon the cloth, and when the cloth is subsequently passed through the colouring bath, only those parts to which the mordant has been applied will receive a permanent stain; for although the whole piece will be coloured, those parts which are untouched by the mordant will be easily restored to their original whiteness by washing and exposure to the air. Previous to printing, the cloth undergoes a variety of processes, termed the preparation. The first of these is termed *dressing*, and consists in passing the cloth very rapidly over a cylinder of iron, at nearly a white heat, or over a broad flame of gas. It is next *steeped* for twenty-four hours in a weak alkaline lye, at the temperature of about 100°, and is afterwards boiled in a solution of potash, which is called *ashing*, and is then well washed, to free it entirely of the alkali. The next process is called *souring*, which consists in immersing the cloth in water containing about one-twentyfifth part of its weight of sulphuric acid, and being again well washed and dried, the preparation is completed. Previous to the ordinary description of printing, the goods are calendered, which consists in passing them through a set of rollers, which gives them a gloss; but for what is termed copper-plate printing, or cylinder work, the calendering is omitted. In printing fast colours, the printer proceeds as follows: he lays the calico, which has been already smoothed by calendering, upon a strong thick table, covered with a woollen cloth, and proceeds to apply one or more mordants, as the case may require, for fixing the intended colours. The mordants are applied by means of wooden blocks, to the surface of which the pattern, cut out of thick plates of brass or copper, is firmly fixed. When the mordant is ready, it is either

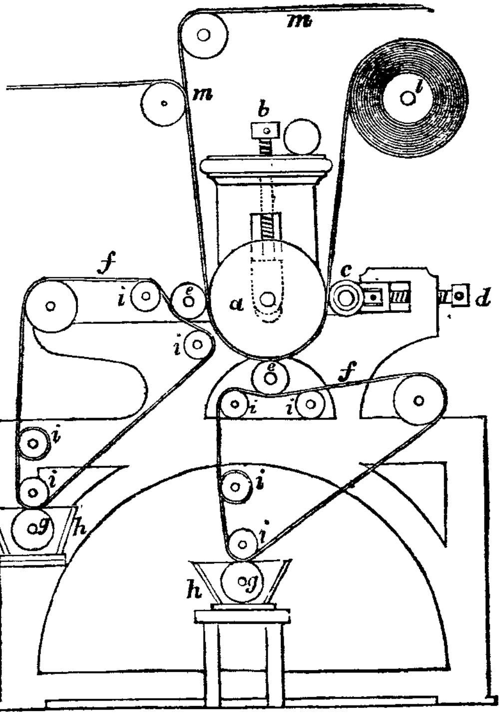
mixed with flour paste, or a thick aqueous solution of gum Arabic, gum Senegal, gum tragacanth, or of what is called British gum, which is merely common starch calcined and pulverized. In this state the mordant is spread upon a piece of fine woollen cloth, strained tight upon a broad hoop. This is called the sieve, and is placed within another hoop, called the case, covered with sheep skin, or oil cloth, and the sieve within its case is placed in a tub of gum water, and is ready for use. The mordant is applied to the surface of the sieve by means of a brush, which is called *teezing;* and should the mordant be colourless, as, for instance, the acetate of alumina, some fugitive dye is mixed with it, to make the pattern obvious to the workman, who, taking the block containing the pattern in one hand, applies it gently to the surface of the sieve, so that a sufficient quantity of the thickened mordant may adhere to the figures. He then applies the block thus charged to the calico, giving it a blow with a small mallet, and continues applying the block alternately to the sieve and to the calico, until he has gone over the whole piece. When the piece is intended to contain a variety of colour, several different mordants are thus applied, as the different colours require different mordants to fix them and render them permanent. The calico is now removed to a room heated by flues, in order to be dried; but this is much better effected by an apparatus shown in the annexed engraving, and consisting of a series of cylinders *a a* made of copper or tinned iron, and



filled with steam, and round which the calico is made to pass in succession. Beneath every two cylinders is a vane *b b* moved by a steam engine, which agitates the air, so as very much to facilitate the drying; indeed, so rapidly are the goods dried by this mode, that although the fabrics be wound from the heap *c* on to the first cylinder perfectly wet, they become thoroughly dry by the time they have passed over the whole apparatus, and fall in a perfect state on the heap *d*. After drying, the pieces are passed by means of a winch through water at various temperatures, with a little cow-dung mixed with it, in order to remove that portion of the mordant which is not actually combined with the cloth, and which might otherwise stain the white or unprinted parts. The pieces are then taken to the river or wash-wheels, to be more effectually cleansed, and afterwards passed through tepid water, in order to insure every impurity being removed. A quantity of madder is next broken into a copper boiler of pure cold water, and a fire is lighted beneath. The ends of several pieces of calico are then skewered together, and immersed in the madder bath, and are kept in constant motion by an apparatus (shown in the article DYEING), driven by a steam engine until the whole attains the boiling temperature, or even for some time after: the colour being by this means uniformly distributed, the pieces are taken out and thoroughly washed. This process, which is called *maddering*, has the effect of imparting all the requisite colours at *one* operation, which may be thus explained: while one mordant precipitates the colouring matter to a red, another precipitates a different portion of it of a purple colour; another precipitates it black, and so of every possible shade from a lilac to a black, and from a pink to a deep red. If a portion of weld or quercitron bark be added to the madder, every shade from an orange to a brown may be produced; whereas, if weld or bark alone be employed, all colours between a dark olive and a bright lemon can be imparted to the cloth. The mordants generally used in calico printing are acetate of iron for browns, blacks, lilacs, &c., and acetate of alumina for all the different shades of reds and yellows When the goods

have passed through the madder or weld copper, they are usually carried to boiler containing wheat bran and water, for the purpose of freeing the white grounds from the stain which they always acquire from the madder, bark, or weld, employed in dyeing the print. It, however, frequently is the case that goods will not bear to be sufficiently branned to clear the whites by that one operation, as branning in some measure impairs the intensity of the colours; such goods, therefore, are partially cleansed in the branning copper, and are then either laid on the grass for some days, until they become perfectly clean and white, or (which is a much more expeditious process) they are immersed for a short time in a very weak solution of one of the bleaching salts, as oxy-muriate of potash, soda, magnesia, &c. There is another method of calico printing styled *resist work*, which is the reverse of that just described, the pattern being printed on a cloth with a certain preparation which *resists* the colour, when the goods are immersed in the dye vat, so that the grounds only are dyed, the pattern remaining white. This process is practised for printing goods in which the grounds are intended to be blue instead of white. To comprehend the principles of this process, it should be understood that indigo, in its natural or oxygenized state, has no affinity for cloth, but that it is deprived of its oxygen by iron, which has a greater affinity for oxygen than indigo has, and the deoxygenized indigo becomes soluble, and is readily fixed on the cloth. Copper, on the contrary, has a less affinity for oxygen than indigo has; the oxides of copper, therefore, when dissolved, give up their oxygen to indigo in solution, which thus acquiring oxygen, is restored to its natural state, and can no longer impart its colour to the cloth. The process of resist work is conducted in the following manner: a solution of some of the salts of copper, as the sulphate, nitrate, muriate, or acetate, is thickened with flour paste and gum, or with pipe-clay and gum; and with this composition applied to the blocks which contain the pattern, the pieces are printed in the manner before described of printing with mordants. The pieces, when thoroughly dried, are then repeatedly dipped in the blue vat, as it is called, which is formed by mixing indigo with lime and sulphate of iron, in such proportions as shall most effectually deoxidize the indigo. In this vat the grounds receive the required depth of colour, but the parts printed with the solution of copper remain undyed, because the deoxidized indigo becomes oxygenated the moment it touches the copper, which parts with its oxygen to the indigo, and occasions it to become insoluble, and consequently incapable of forming a dye. After the goods have been sufficiently immersed in the blue vat, they are washed and passed through diluted sulphuric acid, when those parts which had been printed with the preparation of copper are found to be preserved of a good white, the preparation having effectually resisted the operation of the indigo, although all the other parts of the cloth have received a permanent dye. When the pattern contains a variety of colours, the white parts are subsequently printed by the method already described, (of mordants,) and a bath of madder, weld, or quercitron bark, as the case may be. Resist work, as we have already stated, is employed when blue is to be the predominant colour or ground of the piece; but if the ground is to be white, and the pieces to have only a small object in indigo blue, the colour is printed with indigo deoxidized by orpiment, and commonly called pencil blue, because formerly whatever objects were done with it, were put in with a pencil. This preparation requires to be fixed on the calico before the indigo has time to recover its oxygen from the atmosphere; to protect it from which an apparatus has been contrived, in which the sieve which furnishes the colour to the blocks floats within the colour contained in a vessel, in which the liquid is supplied from an air-tight reservoir, on the principle of a bird fountain, so as always to maintain the liquid in which the sieve floats at the same height. A third method of printing calicoes is that called *discharge work*, which consists in first dyeing the cloth of some uniform colour, by means of some of the common vegetable dyes, and iron liquor, which is always used in such quantity as to cover, or at least to disguise in a great measure, the colours employed with it. The cloth is then washed, dried, and calendered, and then printed with a solution of one or more of the metals in some of the mineral acids, which, dissolving the

son in the parts to which the pattern is applied, restores the cloth to the colour with which it was originally dyed. Thus, if a piece, treated with a decoction of Brazil wood, and dyed black by being passed through iron liquor, be afterwards printed with a peculiar solution of tin, the ferruginous part of the dye will be dissolved, and the printed part will instantly be converted from a deep black to a brilliant crimson. This process is only applicable where all the purposes are attained by simply dissolving the iron which forms part of the colour that is to be discharged; whereas, for the fine and more expensive work, citric acid, mixed with gum or flour paste, is printed on the cloth, and wherever it attaches, the mordant, whether iron or alumine, is discharged, and a delicate white is left in its place. There is another species of discharge work by which the patterns on the beautiful Turkey red bandannas are produced; but as this cannot be properly called a printing process, we refer our reader for a description of it to the article Bandanna. The ordinary sorts of what is called chintz furniture are produced by the process first described, which is repeated one or more times for the superior sorts, varying each time the mordants and the dyeing stuffs; and when the greatest possible variety of colouring is desired, a portion of the white ground is sometimes coloured blue, by putting in with a pencil the preparation called pencil blue; and green is in the same manner produced by applying some of the same colour to parts previously dyed yellow. We shall conclude this article by noticing an improvement which has been made of late years by the introduction of cylinder printing, which has the advantages of superior accuracy and neatness, as well as of greater expedition. In these



printing machines the pattern is engraved on cylinders of copper, or brass, or wood, which supply themselves with the prepared colour during their revolutions, which colour is transferred to the cloth by the latter rolling over the printing cylinder as it is wound from one roller on to another. Many of these machines

are contrived so as to carry two of these cylinders, each of which has a trough of colour attached to it, by which means two different colours may be printed at a time on one piece of calico, and Mr. A. Parkinson, of Manchester, has invented a machine capable of printing at one time, by means of one cylinder and two surface rollers, or by two of the former and one of the latter, three distinct colours. The leading arrangements of this machine are exhibited in the engraving on the preceding page. *a* the main roller of iron, round which the calico passes to receive the impression from the three smaller rollers; *b* one of the screws, to give proper pressure to the main roller; *c* a copper roller, with one of the patterns engraved on it, and pressed against the main roller by the screw *d*. The roller *c* receives colour from a small box at the top, which could not be shown in the engraving. *e* and *e* two wooden rollers, on each of which is cut a pattern; *f f* two blankets, to supply colour to the rollers *e e*. These blankets receive the colour by revolving in contact with the rollers *g g*, turning in the colour boxes *h h*, and the colour is uniformly spread by the rotatory motion, by the time it arrives at the rollers on which it is to be deposited. *i i* are guiding and stretching rollers to the two colour blankets; *k* the guide roller to the blanket which is interposed between the main cylinder and the calico; *l* the roller from which the plain calico is unwound during the process of printing; *m* the calico passing from the printing rollers in a printed state. Mr. Parkes (from whose Essay on Calico Printing the foregoing description of the process is taken,) observes, that not only is the printing more correctly performed by the cylinders than can possibly be done by means of the block, but also the saving of time and labour is so great, that a piece of calico which would take a man and a boy three hours to print with one colour, or six hours to finish with two colours, may be printed by the machines in three minutes, or three minutes and a half, and the work will be much more completely done than could have been even imagined before the introduction of this invention.

CALLIPERS. A sort of compasses, made with bowed or arched legs, and used for measuring the diameter of cylindrical bodies.

CALOMEL. Chloride of mercury, frequently called mild muriate of mercury.

CALORIC. A modern term to denote heat, or the cause by which the phenomena of heat are produced. See CHEMISTRY.

CAMBER. A term applied to that slight degree of arching which is usually given to beams, which see.

CAMEL. A contrivance for lifting ships over a bar or bank obstructing the navigation of a river. It is used in Holland, and some other parts, particularly at the Dock at St. Petersburgh. A camel is composed of two separate parts, whose outside is perpendicular, and the inside concave, so as to embrace the hull of a ship on both sides. They are braced to a ship underneath, by means of cables, and entirely enclose its sides and bottom. They are then towed to the bar, and the water being pumped out of them, the camel rises, lifts up the vessel, and the whole is towed over the bar.

CAMEO. The name given to stones of various colours, which contain ancient sculptures in relief.

CAMERA LUCIDA. An ingenious and elegant invention of the late Dr. Wollaston, for the purpose of facilitating the delineation of objects, by producing a reflected picture of them upon the paper. It consists of a solid prismatic piece of glass, mounted upon a stem capable of elongation or contraction, and which can be screwed at the foot to a table or drawing board. The prism has its angles so arranged, that the rays from the object are reflected upon the paper, and is covered at top by a metallic eye-piece, the hole in which lies half over the edge of the prism, so as to afford to a person looking through, a view of the picture reflected through the glass, and a direct view of his pencil or tracing point. By means of this instrument, a person unacquainted with drawing may delineate objects with great ease and accuracy. For specimens of the capabilities of this instrument, we would refer to the volume of plates to Capt. Basil Hall's *Voyage to the United States of America*, the whole of which, consisting of representations of scenery, animals, portraits, &c. were sketched by means of this instrument by Capt. Hall, who had no knowledge of drawing.

CAMERA OBSCURA. An instrument for a similar purpose as the foregoing, but constructed upon different principles, the rays from the object being caused to pass through a convex glass, on to a white surface placed opposite to the glass, in a darkened chamber. A camera obscura may be constructed as follows: darken a chamber, and into a small aperture made for the purpose in one of the window shutters, fit a lens, either plano-convex, or convex on both sides; and at a due distance, to be determined by experience, place a paper or white cloth, and the objects opposite the lens will be shown upon the paper in their natural colours and proportions, but in an inverted position; by placing a concave lens between the centre and the focus of the first lens, the images will be shown erect. If the aperture do not exceed the size of a pea, the objects will be represented without a lens.

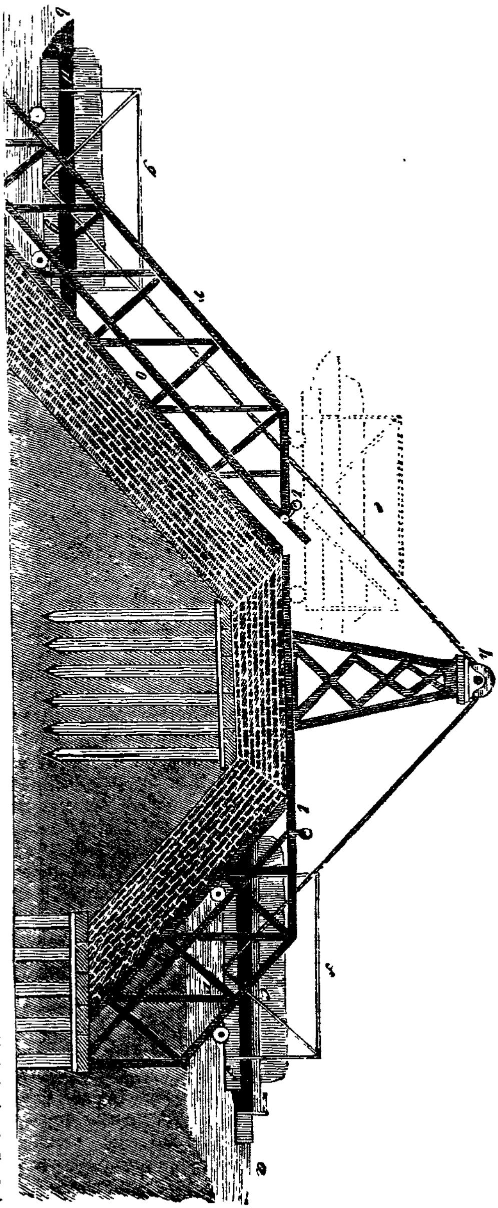
CAMPHOR. There are two kinds obtained from the East, one from Sumatra and Borneo, the other from China and Japan It is extracted from the roots, wood, and leaves of the *laurus camphora*, the roots affording the greatest quantity. It is distilled in large iron pots, to which earthen heads, stuffed with straw, are adapted, and provided with reservoirs. Most of the camphor becomes condensed in the solid form amongst the straw, and part comes over with the water. The refinement of this camphor is performed by sublimation in low flat-bottomed glass vessels placed in a sand bath, and the camphor becomes concrete in a pure state against the upper part, whence it is separated after breaking the glass with a knife. Lewis asserts that no addition is necessary in the purification of camphor, but that the chief point consists in managing the fire, so that the upper part of the vessel may be hot enough to bake the sublimate together in a cake. Chaptal says, that the Dutch mix one ounce of quick lime to every pound of camphor, previous to distillation. Mr. Gray states, that two pounds of quick lime should be added to each hundred weight of rough camphor, and the sublimation be performed in a very gentle heat. Camphor is likewise obtained from thyme, rosemary, and other vegetable substances. Purified camphor is a white, concrete, transparent, extremely volatile, and inflammable substance, of a powerful fragrant odour, and acrid taste. It is insoluble in water, but soluble in alcohol, ether, and the essential oils. It is used in the arts for assisting the solution of resins; also in medicine.

CAMPHORIC ACID. An acid obtained by repeated distillation of nitric acid upon camphor. It appears in the form of crystals, soluble in alcohol, oils, and mineral acids. It also dissolves easily in hot water, but requires about 200 parts for its solution at the ordinary temperature.

CANAL. An artificial cut in the ground, supplied with water from rivers or springs, &c. in order to form a navigable communication between one place and another, and also for supplying towns with water. The advantages to be derived from canals were not unknown to the ancients. Egypt, from the remotest antiquity, contained a number of canals, dug to receive and distribute the waters of the Nile at the time of the inundation; but the most celebrated canal in that country was that which connected the Nile with the Red Sea, which was completed under the second Ptolemy, and was four days' journey in length. It was subsequently neglected, but was afterwards re-opened by one of the caliphs, in 635, after which it was again neglected, so that it is difficult to trace the remains of it at the present day. The aqueducts of the Romans were a species of canal, and they had many also for draining the water from overflowed grounds; and attempts were made (although unsuccessfully) by one of the emperors, to cut through the Isthmus which joins the Peloponnessus to Greece. But China, in the number and extent of its canals, far exceeds all other nations, there being scarcely a town or village that is not washed by the sea or by a river, but has a canal. The Great, or Royal Canal, is the most magnificent work of the kind in the world; it is 825 miles in length, 50 feet in width, and 9 feet deep, and extends from Canton to the northern frontiers of the empire. Most of the countries in Europe are provided with one or more works of this kind: those of Holland, from their number and the admirable mode in which they are managed, have long been the theme of travellers; but perhaps the most stupendous work of the kind is the canal of Languedoc, in

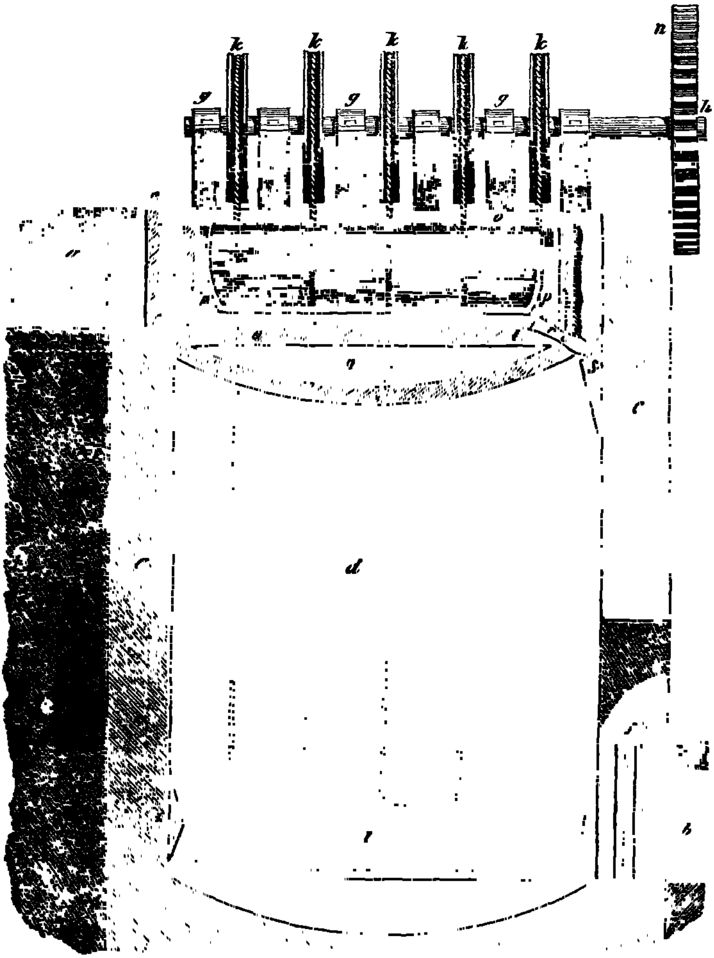
France, which forms a junction between the Mediterranean and the Atlantic. It was begun in 1666, and finished in fifteen years. The breadth is 144 feet, including the towing paths; the depth is 6 feet, and the length 64 French leagues, and it has 114 locks. Although this country at the present day is superior to any nation in Europe (with perhaps the exception of Holland), in the number and magnitude of its canals, it was one of the last to adopt this important improvement; for if we except the New River Cut for supplying London with water, England, up to the middle of the last century, had not a canal worthy of notice; and the honour of their introduction is due jointly to the spirit and perseverance of the Duke of Bridgewater, and to the skill and talents of the celebrated Mr. Brindley. The duke had at Worsley, about seven miles from Manchester, a large estate, rich in coal, which had been hitherto useless, on account of the expense of land carriage; he therefore consulted Mr. Brindley as to the practicability of forming a communication by water, who, having surveyed the ground, and declared the scheme to be practicable, the duke, in 1758, obtained an act to make a navigable cut or canal from the township of Salford, to or near Worsley Mill, and to a place called Hollens Ferry, in Lancashire; but extending his views as the work advanced, he subsequently obtained two other acts, the first to carry it over the Irwell to a place called Longford-bridge, and the second to extend it from Longford-bridge to a place on the Mersey River, called the Hempstones. The whole navigation was then proceeded in and completed, being more than 29 miles in length, and having, at its fall into the Mersey, locks which let it down 95 feet. It should be remarked that the locks were formed at Runcorn, instead of the Hempstones. The completion of these works quickly rendering apparent the important advantages of canals to the commercial and manufacturing interests, new undertakings of the kind succeeded each other with such rapidity, that the bare enumeration of those existing at the present day would occupy more space than we could spare for the purpose. Amongst the principal are the Grand Trunk, or Staffordshire Canal, forming a communication between the Trent and the Mersey, and, consequently, between the German Ocean and the Irish Sea; the Thames and Severn; the Birmingham Canal; Peak Forest and Grand Junction, in England; and the Caledonian Canal, in Scotland. The total number of canals in Great Britain is 103; the total extent 2688 miles; and the capital sunk in their construction is computed at upwards of thirty millions sterling. With two or three exceptions, they were all constructed by the combined exertions of private individuals; and important as these works are now become, none of them were projected prior to 1755. The particular operations necessary for making artificial canals depend upon a variety of circumstances. When the ground is naturally level and unconnected with rivers, the execution is easy, and the navigation not liable to be disturbed by floods; but when the ground rises and falls, and cannot be reduced to a level, artificial means of raising and lowering vessels must be employed. The ordinary expedients are either inclined planes or locks. The first of these methods, viz. the inclined planes, is chiefly resorted to in cases where the canal is so very scantily supplied with water that its economy becomes an object of the first importance. For this purpose, an inclined plane of masonry is constructed, extending from one level to the surface of the next above it, and the boats are hauled up the plane upon a kind of cradle or sledge, furnished with rollers, and this, it is said, was the only method employed by the ancients, who appear to have been ignorant of the nature and utility of locks. The engraving on the opposite page represents an improvement upon this method of passing boats from one level to another, by which the boats maintain their parallelism whilst ascending the inclined planes. It is the invention of Mr. J. Underhill, of Parkfield Iron Works, near Wolverhampton. The following is a description of the engraving: *a* the higher level of the water of the canal; *b* the lower level; the bottom of the canal is a little excavated at each of these places, to admit of a kind of cradle carriage to be sunk sufficiently deep for a boat to be floated on to or off it. At *c* is represented a laden boat, placed upon the upper level in its carriage *f f*; and at *d* another, similarly circumstanced upon the lower level, in its carriage *g g*. Each of them

is attached by strong chains to a drum-wheel *h*, properly mounted in a strong framing, and worked by a steam engine or other adequate power. The carriages are mounted upon two pairs of solid iron wheels, which run upon railways that connect the upper and lower levels. These railways form two inclined planes for the ascent of the carriage, and the same for its descent, whilst the two slopes are connected at top by a horizontal plane. This will be clearly understood by reference to the diagram. The boat *c* is there represented in its carriage, and ascending the double rails or planes *r*, the hind wheels being on the top rails, and the fore wheels on the bottom rails, but confined in their track by the parallel bars *o* above, which preserve the carriage from shifting out of the horizontal position. Before arriving at the top, the fore wheels open two latches *l*, having counterbalance weights, and both hind and fore wheels arrive together on the top of the horizontal line of rail. On drawing it forward for the descent into the lower level of the canal, the latches *l* become closed, and the carriage is sent forward, as shown by the dotted lines at *e*, before descending, when the fore wheels open the latches for the hind wheels to enter between the parallel bars; *g g* shews the boat and carriage delivered on to the lower level of water, where the carriage sinks to a sufficient depth to allow the boat to float away from it. The patentee proposes to employ similar machinery for raising weights on land. But where canals have an abundant supply of water, the usual method of transmitting boats from one level to another is by locks. A lock is a long narrow passage connecting two contiguous levels, of sufficient width and length to receive a boat, and in depth extending from the top of the upper level to the



bottom of the lower level. The sides are usually formed of masonry, and at each end is a pair of strong gates, turning upon centres strongly secured to the walls. The gates next the upper level extend only to the bottom of that level, but those at the lower level extend the whole depth of the lock. These gates are opened and shut by means of long projecting arms or levers, and when closed, the gates meet in an angle pointing up the stream. At the upper end of the lock is a sluice, by which the water can be admitted into the lock from the upper level; and at the lower end is another sluice, by which the water can be discharged from the lock into the lower level. The operation of passing a boat from one level to another is as follows: suppose it be required to pass the boat from the upper level to the lower, and that the water in the lock is at the same height with the water in the lower level, and that the gates at each end of the lock are closed; the sluice at the upper end is first opened, and the water admitted into the lock from the upper level; and when it attains the same height in the lock as in the upper level, the sluice is shut, the upper gates opened, and the boat hauled into the lock. The upper gates are then closed, the sluice at the lower end of the lock opened to discharge the water into the lower level, and when the water stands at the same height in the lock as in the lower level, the sluice is shut, the lower gates opened, and the boat hauled out of the lock into the lower level. In the reverse operation, or passing a boat from the lower level to the upper, the water in the lock is first reduced to the height of the water in the lower level, when the lower gates are opened to admit the boat into the lock, after which they are closed, and water admitted into the lock from the upper level, until it stands at the same height in each, when the upper gates are opened, and the boat passed into the upper level. The operation just described is extremely simple and easy, but it will be seen that at each transit of a boat in either direction, a lock full of water is drawn from the upper pond and lost. This loss is of such consequence on some canals, that the water is pumped back to the upper level by a steam engine, and numerous plans have been proposed for avoiding or lessening this loss. On the Regent's Canal the locks are double, and placed side by side, with a sluice in the middle pier to admit the water from one lock into the other. In passing a boat from the upper to the lower level by these locks, the water is not discharged from the full lock into the lower level, in the first instance, but it is admitted into the empty lock until it stands at the same height in each; after which the sluice in the middle pier is shut, and the remainder of the water discharged into the lower level, by which means only about half a lock full is lost at each transit. Mr. Brownill, of Sheffield, has proposed a plan for passing boats from one level to another, with very little loss of water, which we shall endeavour to describe with the assistance of the engraving on the following page, which represents a vertical section of the apparatus. *a* is the upper level of the canal; *b* the lower level; *c c* section of the end walls of the shaft in which the cradle works; *d* one of the side walls of the same; *e* the gate of the upper level; *f* the gate of the lower level; *g g* a number of bearings, supporting the horizontal axis *h*, on which are placed the large sheaves *k k*, over which the suspending chains run; to one end of these chains is attached the cradle *o*, and to the other end is hung the counterbalance *l* (shown in dotted lines), which rises and falls in a side shaft, there being a similar counterbalance in another shaft on the opposite side of the main shaft *d*; these two counterbalances are made to act together by means of the large wheel *n* acting on a similar wheel on the axis of the opposite counterbalance. This arrangement the inventor terms his double union lift. The cradle *o* has a sluice at each end, fitted with smaller sluices *p p*; it has also a double bottom *q*; *r* is a short lever at the lower end of the cradle, which does not prevent its ascent, but as soon as it arrives above the inclined plane *s*, its upper end turns over, and rests against the dotted lever *t*, termed the release lever; and upon allowing the cradle to descend a little, the lever *r*, acting upon the inclined plane *s*, forces the cradle over against the sill of the gate of the upper level. At the opposite corner of the cradle is a similar apparatus (not shown in the drawing,) to act upon the inclined plane *x*. To pass a boat from the lower level to the upper one, the cradle is forced by

the pressure of the lever upon the inclined plane x, close over to the entrance of the lower level; the small sluices $p\ p$ are then opened to admit the water into the cradle, until it stands at the same height in it as in the upper level, when the larger sluice in the cradle and the gate f are opened. The boat is now hauled into the cradle, after which the gate and sluices are again closed, and the counterbalances (which consist of large iron tanks filled with water), being at the top of their shafts, as much water is let out from the double bottom q of the cradle o as will cause the counterbalances to preponderate when they descend, and thereby cause the cradle containing the boat to ascend and pass the inclined



planes s; but as there is a small portion of water in the side shafts, the counterbalances are checked in their descent on reaching this water; they then rise slightly, and allow the cradle to settle on the inclined plane s, which forces it against the upper level; the small sluice p is next opened, and as soon as the water stands at the same level on each side of the large sluice, the latter and the gate of the canal are opened, and the boat can then pass into the upper level. If now a boat is to be passed from the upper to the lower level, it is hauled into the cradle; the gate e and the large sluice, and the smaller sluice p are all

shut, and as much water is admitted in the double bottom p of the cradle (from a side reservoir, shown dotted,) as will give the cradle a preponderance; and the release lever being let go, the lever r turns over, and the cradle descends, and on reaching the bottom of the shaft it is passed into the lower level in the manner described for passing it into the upper one. The ends of the cradle must be covered with stuffing of some kind, to prevent as much as possible the escape of the water when the sluices are open.

CANDLE. A cylindrical mass of tallow, or other concrete oleaginous matter, having in its axis a cotton or other wick, and employed to afford artificial light. Next to tallow, the substances most extensively used are wax and spermaceti. Some valuable substitutes for these have recently been discovered and introduced in the manufacture of candles, which we shall give an account of in this article, after having described the processes employed in the production of the former. There are two sorts of tallow candles, *dips* and *moulds;* the former being made by dipping the wicks in melted tallow, the latter, by casting, or pouring the fluid tallow into moulds containing the wicks stretched longitudinally throughout their centres. The cotton used for making the wicks is loosely twisted, and is prepared for the manufacturer in large balls, who draws out a thread from each of five, six, or more balls, (according to the thickness of wick required,) and cuts them off to the length of the intended candle. The apparatus for cutting the cotton is simply a smooth board, made to fix on the knees; on the upper surface is the blade of a razor, and at the required distance a piece of cane is fixed, around which the cotton is carried, and being thence brought over the edge of the razor, is instantly separated. The next operation, called "pulling the cotton," consists in drawing the threads through the hand, and removing knots or other unevenesses. The cotton is next "spread," or extended between two rods, about half an inch diameter, and three feet long; these are called broaches. In dipping candles by hand, the workman takes two broaches at a time, strung with the proper number of wicks, and holding them equidistant by means of the second and third fingers of each hand, he immerses them in a vat containing the fluid tallow, three times successively for the first lay or coat, then holds them for a while over the vessel to drain, and afterwards suspends them on a rack above, where they continue to drain. When this first coating of tallow has solidified, the workman proceeds in like manner to give them their second coat, by dipping them twice before hanging them again to drain and cool. The number of lays or coats thus given to the candles depends upon the thickness they are required to be. During the operation the vat is supplied from time to time with fresh tallow, kept at a proper temperature by means of a gentle fire underneath it. Tallow-chandlers have of late years, however, generally availed themselves of a very simple and convenient piece of mechanism for aiding them in their dipping process. Five or six of the broaches, filled with the cotton wicks as already described, are fixed at both their ends into a movable frame, which is suspended over the vat upon one extremity of a lever, and is counterbalanced at the other by weights in a scale, which are increased as the candles become heavier. By this arrangement it is obvious that the workman has only to guide the frame in dipping the candles, and not to support the weight between his fingers, as before mentioned. It is said that other mechanical contrivances have been introduced for the same purpose, but we are not aware of any so simple and efficient. The mould in which moulded candles are cast consists of a frame of wood, and several hollow metal cylinders, generally made of pewter, of the diameter and length of the candle wanted, and having an aperture at each end for the cotton to pass through, which is performed by a wire, the cotton being fastened so as to keep it straight and in the centre of each mould. Tallow being poured into these moulds, the candles are suffered to cool and harden, when they are readily withdrawn out of the tubes. The kind of candles called rush-lights, differ only by their containing a rush as a substitute for the cotton wick, which prevents the necessity of snuffing. Lately, however, small cotton wicks have been introduced, which do not require snuffing; these burn with a steadier light, and are not so liable to go out as those with rushes.

Wax candles are also of various kinds; they are made of cotton or flaxen wicks, and covered with white or coloured wax, which is performed either *by the ladle* or *by the hand*. In making them by the ladle, a dozen of them are tied by the wick at equal distances round an iron ring, suspended over a large basin of copper, tinned on the inside, and full of melted wax; a large ladleful of this wax is gently poured on the tops of the wicks one after another, and the operation continued till the candles arrive at their destined dimensions. The first three ladlesful are poured on to the tops of the wicks, the fourth at the height of three-fourths, the fifth at one half, and the sixth at one-fourth, in order to give the candles their proper form, which are then taken down and smoothed by rolling upon a walnut-tree table, with a smooth box-wood instrument, which is continually moistened with hot water to prevent the adhesion of the wax. In making wax candles by the hand, the workmen begin to soften the wax by working it several times in hot water, contained in a deep narrow cauldron. A piece of the wax is then taken out and disposed by little and little around the wick, which is hung on a hook in the wall, by the extremity opposite to the neck, so that they begin with the large end, diminishing still as they descend towards the neck. In other respects, the method is nearly the same as in the before-mentioned. There is, however, this difference,—that in the former case, water is used to moisten the instruments, while in the latter, the hands are lubricated with oil of olives, or lard, to prevent the adhesion of the wax. Wax tapers are drawn after the manner of making wire. By means of two large wooden rollers the wick is repeatedly passed through melted wax contained in a basin, provided on one side with an instrument full of holes, through which the cylinder of wax also traverses until it has obtained the required size.

Candles are made from spermaceti, the process being very similar to that employed in making them of tallow; they are also made of various mixtures of tallow, spermaceti, and wax; certain proportions of which constitute the article termed composition candles. The meritorious investigations of M. Chevreul, concerning the true nature of fatty substances, which were published a few years ago in the *Annales de Chimie*, appear to have opened a wide and diversified field for the operations of the manufacturer and the experimentalist. By dissolving fat in a large quantity of alcohol, and observing the manner in which its different portions were acted upon by this substance, and again separated from it, M. Chevreul found that fat is composed of an *oily* substance, which remains fluid at the ordinary temperature of the atmosphere, and of another *fatty* substance which is much less fusible. Hence it follows that fat is not to be regarded as a simple principle, but as a combination of the above two principles, which may be separated without alteration. To the former of these substances, which melts at 450° Fahr., and has very much the appearance and properties of vegetable oil, M. Chevreul gave the name of *elain*, and to the latter, which melts at 100°, he gave the name of *stearin*; this is separated from the former by crystallization in the form of small silky needles, while the elain is obtained by evaporating the spirit. M. Bracconet subsequently employed a simpler process to obtain the elain and stearin; he squeezed the tallow between folds of porous paper, which absorbed the elain, leaving the stearin between; the paper being afterwards soaked in water, yielded up its oily impregnation. The principle of M. Bracconet's process is now extensively applied by manufacturers, who employ powerful presses to squeeze the fluid oil from the tallow. In the year 1825, M. Gay Lussac, the celebrated French chemist, also took out a patent for this country for the employment of the stearin (termed likewise *margaric acid* from its chemical properties) in the manufacture of candles; the patent likewise extending to a new mechanical construction of candles. Of the several processes that may be employed for obtaining the margaric acid for this purpose, two are particularly descriptive in the specification, namely, saponification and distillation The first is to be effected by incorporating any of the alkalies with the fat, as is done in the making of soap, and then decomposing the soapy fluid by an acid that has the greatest affinity to the peculiar alkali employed. It is recommended that the decomposition be effected in a large quantity of water,

heated by steam, which should be kept well stirred. Being afterwards allowed to rest, the products will float on the surface in a condensed and solid form. If the tallow or fat, thus purified from the matters soluble in water, should still contain any of the salts employed in the previous process, it is to be washed by additions of fresh quantities of warm water, until they are perfectly discharged. This being done, and the mass of fat having become solid by cooling, it is to be subjected to the action of a powerful press, similar to those used for expressing oil from seeds, when the fluid oleic acid (or elain) will run off, leaving the margaric acid in the press, from which product the candles are to be made. The distilling process is conducted by exposing the fat, in an ordinary still, to the heat of a furnace. Steam is also to be introduced into the still to facilitate the operation, and to carry over those products which are soluble in it, through the worm or condenser, into a receiver. Care must be taken in regulating the heat of the furnace, to prevent discolouring the materials in the still The fat thus prepared is to be purified by washing, and then subjected to pressure as in the previously described process. For the more perfect purification of the fat, both the foregoing operations of saponification and distillation may be combined, and the residue after subjected to pressure. The margaric acid may also be bleached by exposure to the air and sun the same as in the bleaching of wax; the oleic acid, or fluid oil, may also be whitened by similar means, and be applied generally to the same purposes as the vegetable oils. The form of M. Gay Lussac's candles is that of hollow cylinders, through which a stream of air passes to the wick (on the principle of the argand burner in lamps) for the purpose of producing a perfect and vivid combustion of the tallow. He directs that the wick be formed of cotton yarn twisted rather more closely than usual; this yarn is to be wound spirally round a metallic rod or thick wire, in the same manner as wire is sometimes coiled round the large strings of musical instruments. These rods, covered as described, are to be inserted into the moulds used for making candles; and when the candles have been cast, and the tallow become hard, the wires are to be withdrawn, leaving the wicks behind in the candles with a perforation, or air passage, equal to the size of the rods, throughout their whole length. We have thought it proper to introduce this account of M. Gay Lussac's specification of his patent, because it affords clear and judicious instructions in conducting similar operations. The processes possess scarcely any originality in the mode of procedure; and as regards the invention of the candle itself, the French chemist is just twenty years behind two of our own countrymen, namely, Messrs. Desormeaux and Hutchings, who took out a patent for the identical contrivance in the year 1805. It is perhaps worthy of notice here, that this invention affords a very remarkable proof that many individuals may, without communication or knowledge of each others' ideas, invent precisely the same thing. The writer of this article, about ten years ago, spontaneously thought of the same contrivance, and made a candle of the kind, which is represented in the annexed cut. The dotted lines at *a* mark out the central aperture for the air; and the wick, which is bedded in the middle of the thickness of the hollow cylinder of tallow, is a common argand wick. This candle, although not fabricated in a workmanlike manner, gave good indications of success under proper management. Upon mentioning the project to some friends, we learned to our surprise that several other persons had entertained the same propositions, each person imagining himself to be the sole inventor. In like manner we were informed by the before-mentioned gentleman, Mr. Desormeaux, that he had patented the invention at the time stated; that a large manufactory was commenced for the purpose of making the article, with every probability of success; and that the reason why the manufacture of them was not carried forward, had no reference to the practicability of the scheme. Seeing that the subject has been

taken up by scientific as well as practical men, we are confirmed in our opinion that important results may yet flow from prosecuting the plan, if undertaken by some intelligent person. We are not wholly indebted to the animal kingdom for a supply of the material for candles, several vegetable oleaginous substances having been recently introduced as valuable substitutes. On the 2d of November, 1829, a patent was granted to Mr. John Soames, jun. of Spitalfields, for the right of separating the constituent principles of the cocoa-nut oil of commerce, which, from its consistence at ordinary temperature, is also called "butter of cacao." Before the date of this patent, cocoa-nut oil was of very limited utility, owing to the presumed necessity of artificial heat to render the mass sufficiently fluid to be burned in lamps, and to that apparent want of solidity which is required in the manufacture of candles. Mr. Soames's process for separating the fluid from the solid matter in cocoa-nut oil is as follows:— the oil is put into strong linen bags, 2 feet long, 6 inches wide, and 1¼ inch thick; these are covered with stout sack-cloths made for the purpose, and are laid flat upon the horizontal bed of a hydrostatic press, leaving a small vacant space between the bags. Pressure is then given to them, and continued until the oil ceases to flow, or is only given out by drops slowly. This oil being received into a cistern, is allowed to stand a little time to deposit its impurities, after which it is drawn off clear, and preserved for burning in lamps, &c. The solid portion being now taken out of the bags in the press, is next to be purified from the other vegetable principles with which it is usually combined, such as fibre, mucilage, &c. For this purpose it is put into a covered boiler of tinned copper, which is immersed in a water-bath to prevent the liability of an excess of heat; there is then added to it two parts, (or two per cent.) by weight, of sulphuric acid, of spec. grav. 1.8, diluted with six parts of water. Boiling then coagulates and precipitates the foreign matters, which may be separated by skimming, straining, or filtering, while warm in the fluid state, and by allowing them to settle in the cold state. The substance thus obtained is of firm consistence, and forms a valuable material in the making of candles that are now extensively used. In the *Quarterly Journal of Science*, an interesting account is given of the piney tallow tree of India, which we introduce in this work, as the writer observes, that "it may be imported into this country at less than one-fourth the price of wax; and that although it does not possess all the advantages of that substance, it is considerably superior to animal tallow." This substance, he says, "is a concrete inflammable, partaking of the nature of wax and oil, which, from its appearance, may not inaptly be termed a tallow. It is in use only in the town of Mangalore (province of Canara), and is there employed medicinally as an external application for bruises and rheumatic pains; and likewise, when melted with the resin of the same tree, is used as a substitute for tar in paying the bottoms of boats. The method of preparing this material is simply to boil the fruit in water, when the tallow is soon found to rise to the surface in a melting state, and on cooling forms a solid cake. Thus obtained, the piney tallow (piney is the native name of the tree which produces it) is generally white, sometimes yellow, greasy to the touch, with some degree of waxiness, almost tasteless, and has a rather agreeable odour, somewhat resembling common cerate. It melts at a temperature of 97½°, and consequently remains solid in the climate of India, in which respect it differs from palm or cocoa-nut oil: wrapped up in folds of blotting paper, and submitted to strong pressure, scarcely sufficient oil, or elain, as it is termed by M. Bracconot, is expressed to imbue the inmost fold. Its tenacity and solidity are such, that when cast in a rounded form of nine pounds' weight, the force of two strong men was not sufficient to cut it asunder with a fine iron wire, and even with a saw there was considerable difficulty in effecting a division. When manufactured into candles, it comes with facility from the moulds, thus differing from wax, which does not readily admit of being cast; it gives as bright a light as tallow, and has the advantage of that material in being free from unpleasant smell, and in not emitting a disagreeable odour when extinguished. It unites, in all proportions, with wax, spermaceti, and tallow; and forms compounds with the two former, intermediate in their melting points,

according to the proportion in their ingredients, and better adapted to the purpose of making candles than the pure and more fusible substance itself." With the view of ascertaining the comparative combustibility of piney tallow, candles of the materials undermentioned were cast; one mould was used for all, and the wicks were composed of an equal number of threads. Having been accurately weighed, they were burned for one hour in an apartment in which the air was unagitated, and at a temperature of 55°.

	Weight in grains when lighted.	Weight at the end of one hour.	Loss
Wax	840	719	121
Half wax, half piney tallow	770	631	139
Spermaceti	760	604	156
Half sperm, half piney tallow	777	625	152
Animal tallow	811	703	108
Half tallow, half piney tallow	792	681	111
Cape wax	763	640	123
Piney tallow	812	702	110

In the year 1830, a solid substance, resembling wax in most of its properties, was obtained by M. Manicler, a French chemist (lately deceased), from palm oil, an English patent for which was taken out in conjunction with Mr. James Collier. The specification states that the process consists in placing the palm oil, or butter of palm, in a metallic vessel or boiler, made of tinned iron, and provided with a close cover and safety valve, upon the principle of Papin's Digester; water, in the proportion of about one-sixth part to the substance being added. The vessel being well closed, it is submitted to the action of fire, so as to raise the steam to a pressure of two or three atmospheres, which operation is to be continued for two hours. After the material has been thus prepared, it is to be put into wrappers of linen or woven horse hair, or both may be used, and submitted to powerful pressure: by this means the elain, or fluid oil, is separated, and the stearin remains in the wrappers in a solid state. Both these products are of a yellowish brown colour, and require a process of bleaching to deprive them of it. We have seen candles made from the stearin of palm oil, which were very little inferior to wax in illuminating power; they were cast in moulds, from which they readily separated by contraction when cold, in this respect possessing an advantage over wax. The odour emitted by the substance is like palm soap, and is generally considered rather agreeable than otherwise. It may, perhaps, be necessary to explain to the general reader that the palm oil of commerce, and that to which the last mentioned patent relates, is the produce of a tree growing abundantly in Africa and South America, where, as well as in other parts of the world, it is obtained from the outer shell or pulpy rind of the palm nut, while the kernel of the nut contained within the inner indurated shell is thrown away as useless in the preparation of oil or other oleaginous articles of commerce. These *kernels*, however, have been recently found to abound in oleaginous matter of superior quality, eminently calculated for the production of candles, besides generally for those purposes for which fluid and concrete oils are used. For the introduction and application of this valuable (*refuse*) matter, the public is indebted to Mr. John Demeur, who has recently taken out a patent for this interesting discovery. The process described by the patentee in his specification is as follows: "I first subject the kernels to a slight heating in an oven, or other convenient apparatus, carrying the process only so far as to render the kernels comparatively crisp and brittle when cold, which facilitates the subsequent operation of grinding them to a paste in a mill. This paste I dilute with one-fourth of its weight of boiling water, and then put it into bags (of the usual kind employed in oil mills), wherein I subject it to mechanical pressure by the ordinary mechanism employed for similar purposes, preferring, however, to place the said bags containing the paste between heated metallic plates. By the joint action of heat and pressure so applied, the oleaginous matter is

copiously exuded through the interstices of the bags, and is collected in suitable receivers to undergo a purification. This purification I usually effect by remelting the last mentioned product, and filtering it whilst in a fluid state; and if it be desired to purify or refine it still farther, or to remove the slight tinge of colour it may yet possess, I again melt it in a metallic vessel coated with tin, and mix therewith, by agitation or stirring, some very dilute sulphuric acid. By this process the impurities are precipitated, or subside, by rest, to the bottom of the vessel, and the oleaginous matter floats above the water, whence it is removed, and subsequently consolidated, by evaporating the aqueous particles that were commixed with it in the previous operation. The product resulting from the last described process is a white and partially concrete matter, as it consists of the two distinct substances, termed elain and stearin, the former of which is fluid, and the latter solid, at our ordinary atmospheric temperature. To separate these, they are subjected again in bags to mechanical pressure, without the aid of artificial heat, if the weather be warm; but if the air be under 65°, the application of a slight degree of heat will assist the operation, and cause a fine fluid oil to be expressed, leaving the stearin in the bags of a similar consistence to wax or spermaceti, and from which candles, scarcely inferior to those fabricated of the last mentioned substances, and very superior to those of tallow, are made. Having noticed the several important materials that have been introduced into the modern manufacture of candles, we shall proceed to describe some very recent and ingenious improvements in their construction and composition, which have been the subject of patents.

Dr. Bulkeley, of Richmond, in Surrey, took out a patent, dated January 26, 1830, for a plan of making tallow candles with an exterior casing of wax, and also for effecting a saving in the material used for wicks, as well as to obviate the necessity of snuffing. He uses a metallic mould, of the description generally employed in the manufacture of mould candles, and fills it with melted wax. Now, as the portion of the wax which is in contact with the interior surface of the mould will become, by the conducting powers of the metal, first cooled or set, as it is termed, the wax remaining fluid in the centre of the mould is poured off, leaving within the mould a hollow cylinder of wax, which is afterwards filled with tallow, or any other material which melts at a lower temperature than wax. With respect to the wick, the patentee introduces a small thread up the centre of the candle, for the purpose of constituting a guide for a short cotton wick, which is plaited with a piece of straw within it, to receive the thread. This short wick rests on the surface of the tallow, which it raises by its capillary attraction for the supply of the combustion; and as it descends upon the thread as the tallow is melted, the top of it is never removed so far from the tallow as to carbonize and require snuffing, which is the case with wicks of the ordinary construction. The ordinary mode of manufacturing wax candles, described in the early part of this article, has, we understand, been resorted to, on account of the presumed difficulty of removing them from the moulds, to which they firmly adhere, if cast therein. To obviate this difficulty, Dr. Bulkeley places a block of box-wood, having a cavity in it to receive the lower ends of the candle, in contact with the annular edge of the mould; then striking the block a few smart blows with a mallet, he detaches the candles from the moulds.

A patent was also granted on the 4th February, 1830, to Mr. Charles T. Miller, of Piccadilly, Westminster, for certain improvements in making candles. These consist in the use of a small glass ring, which is placed over the wick, and descends as the candle burns. The object in view is to prevent the candle from wasting or guttering, which it effects by the glass ring conducting a greater quantity of heat to the centre of the candle than that which reaches the exterior; so that candles provided with this ring burn hollower in the centre than others, and the exterior tallow, or composition of which the candles are made, stands higher, and descends to the wick as soon as it is melted. The method of manufacturing the candles with the glass rings, as described by the patentee, consists in putting the ring over the wick after it has been placed in the centre of the mould, which, being inverted, as it is while being filled with the oleaginous

matter, the ring descends until it reaches that part of the conical extremity of the mould which is equal in diameter to the exterior of the ring, when it rests, and becomes fixed in the candle. From an experiment which we have witnessed with spermaceti candles, made by Mr. Miller according to the plan described, they appear to answer the purpose intended.

Mr. John Murray, in a letter to the editor of *Brewster's Journal*, states that tallow candles may be materially improved by previously steeping the cotton wicks in lime water, in which there has been dissolved a considerable quantity of the nitrate of potass. The chlorate of potass is preferable to the nitrate, but the great expense of the former salt precludes its employment on the large scale. The wicks should be well dried before the tallow is put to them. By this process, Mr. Murray states that the candles afford a purer flame and a more brilliant light; the combustion of the wick is so complete as to render the snuffing of them nearly superfluous; and that they do not run or gutter.

With similar objects in view, Mr. William Palmer, of Wilson-street, Finsbury-square, London, obtained a patent, dated 10th August, 1830. He applies to about a tenth portion of the strands composing the wick, a quantity of bismuth in a finely divided state, or else the nitrate, or any other similar preparation of bismuth. The portion of wick thus prepared is to be surrounded with more strands, till it becomes half the thickness required for the wick. It is then to be cut into pieces, corresponding in length with twice that of the candle for which it is intended. The wick is next twisted spirally round a thick wire in contrary directions, a notch being made in the lower end of the wire to receive the middle of the wick; and the upper end is bent into a rectangular loop, to retain the two ends of the wire together, and to facilitate its removal when the making of the candle is completed, which is to be effected by either moulding or dipping in the usual manner. The combustion of the wicks of candles manufactured in this way, with a portion of bismuth in combination with the wick made of the double spiral form, causes the two upper extremities of the spiral, in the act of burning, to curl over to the opposite sides of the candles, where they are accessible to an additional quantity of oxygen, and the combustion is in consequence so intense as to leave no carbonaceous matter to impede the light, or to require removal by snuffers. We shall close our article on this subject by the translation of a French *Brevet d'Invention*, granted to M. Lorraine, of Paris, for the manufacture of perfumed imitative wax candles, which we think is calculated to afford some useful practical hints to the British tallow chandler. "Candles made of tallow only," observes M. Lorraine, "are unctuous, opaque, greasy, little sonorous, especially in summer, liable to run or gutter, and readily acquiring a rancid smell. These inconveniences are avoided by putting fat, which has been melted and run into cakes, to ferment in a stove where the heat is moderate; this fat distils, and throws off an oily liquor, which is removed with a piece of linen or a sponge. To free the grease from the fleshy and fibrous parts by which it is accompanied, it is first chopped, and after being washed in several waters, it is boiled with a given quantity of Roman alum. The alum soon separates and destroys the heterogeneous parts, and we obtain a pure clear fat, which will last a very long time. The fat chopped and melted, is run into buckets full of water distilled from aromatic simples, such as lavender, thyme, rosemary, &c. The fat and water are beaten together with a spatula, to effect an union. After forty-eight hours the fat is separated from the water, by means of a water bath; the water alone is disengaged, and the aromatic and odoriferous parts remain incorporated with the fat. To complete the purification, the fat is liquefied and scummed, till no foreign substance nor water remains: this will be known by the limpid state of the fat, which then yields only a pure white scum. Still greater purity is obtained by a second quantity of alum incorporated with the tallow. Before casting or running the candles, a composition is made of half wax and half spermaceti, which serves to prepare the wicks. This composition, harder and more cohesive than the tallow, makes the candles less subject to gutter, to become firmer, last longer, and require less snuffing. At the moment of removing the pure liquefied tallow from the fire to cast the candles, a certain quantity of gum Arabic, dissolved in water,

and united with a small quantity of wax and alum, is incorporated with it. The whole are beaten together; and when the tallow has settled well, and cooled to a certain temperature, it is poured into the moulds. By this preparation, in proportion as the cooling takes place, the foreign substances proceed to, and fix at the surface of the candles, forming a kind of covering pleasant to the touch, like wax candles. This covering also prevents the candles from guttering, and enables a person to handle and even rub them without greasing the fingers, and without communicating any other smell than that of the aromatics entering into the composition. The last operation for preventing the guttering of the candles when burning, and giving more solidity to them, is to prepare some glover's size very weak, and boiled with another quantity of gum and alum, and to pass a hair pencil dipped in this size, all over the candles, and the next day after they may be used. Candles prepared in this way are clear, transparent, sonorous, and last longer than others; they feel like bougies, and have the colour of pure wax."

CANNON. In military affairs, a long cylindrical tube for throwing projectiles by the explosion of gunpowder, of such dimensions as to require to be supported upon a carriage, with liberty to recoil after firing; in which circumstance it differs from fire-arms of the smaller sort, as pistols, carabines, &c. which may be fired from the hand or shoulder, and from an intermediate class, as musketoons, duck guns, &c., which are fired from a rest. The date of the invention, and the name of the inventor, are unknown: it is certain that Edward employed cannon at the battle of Cressy, A. D. 1346; but records are extant showing that they were known in France as early as the year 1338; and Isaac Vossius asserts that they were used in China 1700 years ago. For some time after the invention of cannons in Europe, they were formed of bars of wrought iron, fitted together lengthways, or of sheets of iron, rolled up and fastened together; and in both cases hooped with iron rings. They were extremely heavy and cumbersome, and principally used for throwing large stones to short distances, like the machines of the ancients which they succeeded. These were gradually supplanted by brass cannon of much smaller calibre, and which threw iron and leaden balls instead of stones. These guns were first cast of a mixture of tin and copper, and from that circumstance called gun-metal; but subsequently, as the use of cannon became more general, cast iron guns were used on account of their being much cheaper; and at present, guns for the naval service, and for batteries, are generally cast of iron, whilst field pieces and horse artillery, are mostly formed of brass. When the process of casting guns was first resorted to, the guns were cast with hollow chambers, which were afterwards perfected by boring; but the present practice is to cast them solid, and form the cavity entirely by boring. In 1828 a patent was granted to Mr. Joshua Horton, for a method of forming cannon, and other large cylinders, of wrought iron or steel, or mixtures of both. The process is as follows:—A number of bars *a a* are to be bound together by binding hoops *b b*, as shown in *Figs.* 1 and 3, and placed in a furnace. When they have acquired a welding heat, they are to be withdrawn and placed on a maundrel, and hammered together by heavy hammers, and if necessary, heated again until they are perfectly united; the bars should be wedge shaped, or wider on the outside than on the side which is to form the interior of the cylinder; but any of the forms shown in *Fig.* 1 will do. If the cylinder is intended for a cannon, the bars should be thickest at the breach end; and if deemed necessary, the interior may be formed of steel, by placing a layer of steel bars within the iron bars. The breach-piece may either be formed in one piece with the rest, or it may be forged separately and screwed into the gun, as shown in *Fig.* 4. The trunnions may also be formed with the gun; but the patentee recommends that they should be formed in a separate ring, and attached to the gun either by an external screw cut on the gun, and fitting into an internal screw in the ring, as shown in *Fig.* 4, or by keys, as in *Fig.* 2. These separate trunnions the patentee recommends as possessing great advantages, from the facility with which the gun may be rendered useless by removing the trunnions, when necessary to abandon it to the enemy. After the welding is completed, the piece is to be finished by turning and boring. At the first mention of this

method of constructing guns, it seems similar to that followed at the first introduction; but the earlier cannon formed of iron bars were merely hooped together, and not welded, as may be seen in several which are preserved at the Tower of London: nevertheless, it is certain that cannon of smaller calibre,

Fig. 2.

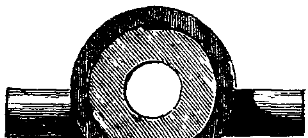


Fig. 1.

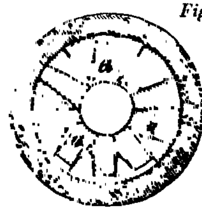


Fig. 3.

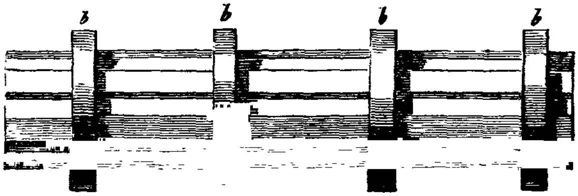
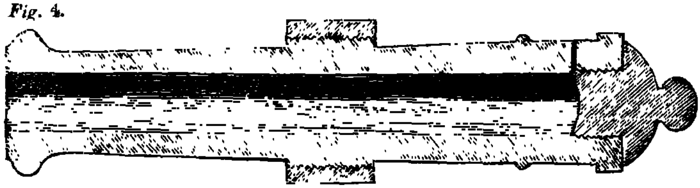


Fig. 4.



forged of iron, were very early known. In proof of this we may cite the following curious fact:—In the year 1827, a fisherman whilst fishing in a boat eight miles to the eastward of Calais, brought up in his net from the bottom of the sea a small piece of ordnance of a very singular construction, resembling exactly the representations of cannon in three ancient historical paintings in the dining parlour at Cowdry, in Sussex, one of the seats of the late Lord Viscount Montagu. The first painting represents the march of King Henry VIII. from Calais towards Boulogne; the second, the encampment of the English forces at Marqueson; and the third, the taking of Boulogne, in 1544. The resemblance will be instantly perceived by referring to the sketch on the following page; *Fig.* 1 representing the cannon as seen in the paintings, and the other figures exhibiting with all its details the cannon taken by the fisherman. *Fig.* 1 represents a carriage supporting two pieces of ordnance, which are nearly covered by a kind of hood in form somewhat like half a cone, the broadest end being next to the shafts, and the smaller end being constructed with sharp points; the hood probably being intended as a shield to protect the artillery men from the fire and arrows of the enemy, and the points as some defence against a charge. *Fig.* 2 is a horizontal view of the new found gun; *Fig.* 3 a longitudinal section of the same; and *Fig.* 4 a bird's-eye view of it; *l* representing the tail bit, also of iron, forming part of the cannon, and serving to adjust it with ease in taking aim. The gun when first brought up from the bottom of the sea was covered with a sort of petrified rust, about two inches thick, which being removed, the diameter of the gun at the middle was found to be 3 inches, its bore for the passage of the bullet 1¼ inch, and the length, including the tail-piece, 5 feet 11 inches, and its weight 64 lbs. Upon examination it was found to be still charged, having in it powder and a *leaden* bullet; from which circumstance we may conclude that cast iron balls were not known at the time when the cannon had been

charged. The bullet had a covering of tow, and weighed 9 ounces; its diameter 1.4 inch. A A and C in *Figs.* 2, 3, and 4, are three different views of a shifting breech, which was detached and taken out of the after part of the gun when required to be loaded with powder; this being charged, and the cartridge properly secured by driving down an oaken plug over it, the bullet was put into the gun at the breech, and the shifting breech replaced in its original position, and firmly secured by an iron wedge D D D, *Figs.* 2, 3, 4, driven in behind it horizontally across the gun. The shifting breech is shewn separately in *Fig.* 5,

Fig. 1.

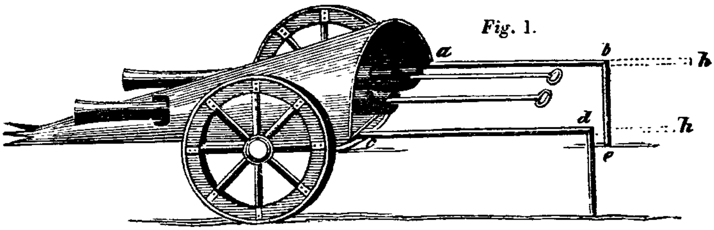


Fig. 2.

Fig. 3.

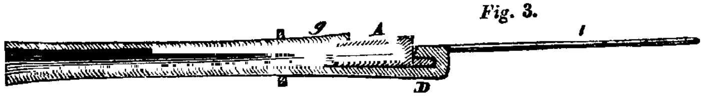
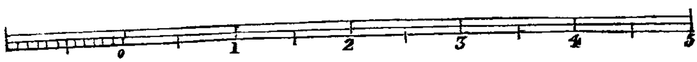


Fig. 4.

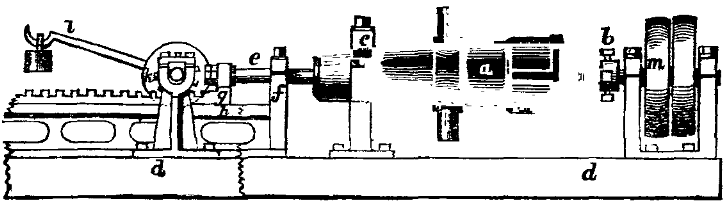
Fig. 5.

Fig. 6.

Fig. 7.

and the wedge in *Fig.* 6. E, *Fig.* 7, is the figure of the after part of the barrel of the gun, and F is the other half within the dotted circumference, this being cut off so as to take out and replace the shifting breech with facility. *g g*, *Figs.* 2 and 3, show the leaden bullet in front of the shifting breech. It is a remarkable fact that the shifting breech appertaining to this cannon is similar in principle to the *patent* shifting breech on some fowling-pieces of modern times.

We shall conclude this subject with a description of the apparatus employed for boring cannon. Formerly the cannons were suspended in sliding frames vertically over the boring tool, and the tool was made to revolve, the cannon descending

gradually as the tool bored the interior; but in the present method of boring, the gun is supported horizontally in a lathe, and revolves, the cutter advancing in a right line. An apparatus of this description is represented in the accompanying figure. The cannon *a* is accurately centered in the chuck *b*, and the collar *c*, which may be set at any part of the bed *d* of the lathe to suit the



length of the gun; *e* is the boring tool, supported by bearings in the frame *f*, and connected to the rack *g*. The rack is made to advance in a chase mortice *h*, by means of a pinion *k* actuated by a weighted lever *l*. The cannon is caused to revolve by a band passing over the rigger *m*, and the operations of boring the interior, and turning the exterior, are carried on at the same time.

CANOE. A sort of boat or vessel used by the natives of various uncivilized countries. They are generally composed of the trunk of a tree hollowed out, and are usually impelled by paddles instead of oars. The most singular canoes are those of the Ladrone Islands, which are adapted to sail with either end foremost, so as always to expose the same side to the wind. From their great velocity when sailing, they are commonly called the "Flying Boats," the Spaniards declaring that they have been known to go 35 miles per hour.

CANTHARIDES. Insects vulgarly called Spanish flies: they are chiefly used on account of their vesicating or blistering properties. The insect is about two-thirds of an inch in length and one-fourth in breadth, oblong, and of a gold shining colour, with soft wing sheaths, marked with three longitudinal stripes, and covering brown membranous wings. The genuine cantharides are sometimes mixed with other insects of a square form, with black feet, which possess no vesicating property.

CANTILEVERS. In architecture, pieces of timber projecting horizontally, used to support the eves of a house, a balcony, &c.

CANVASS. A cloth of hemp, unbleached, and of various degrees of fineness; used principally to form the sails of ships, but also by painters, and for a variety of other purposes.

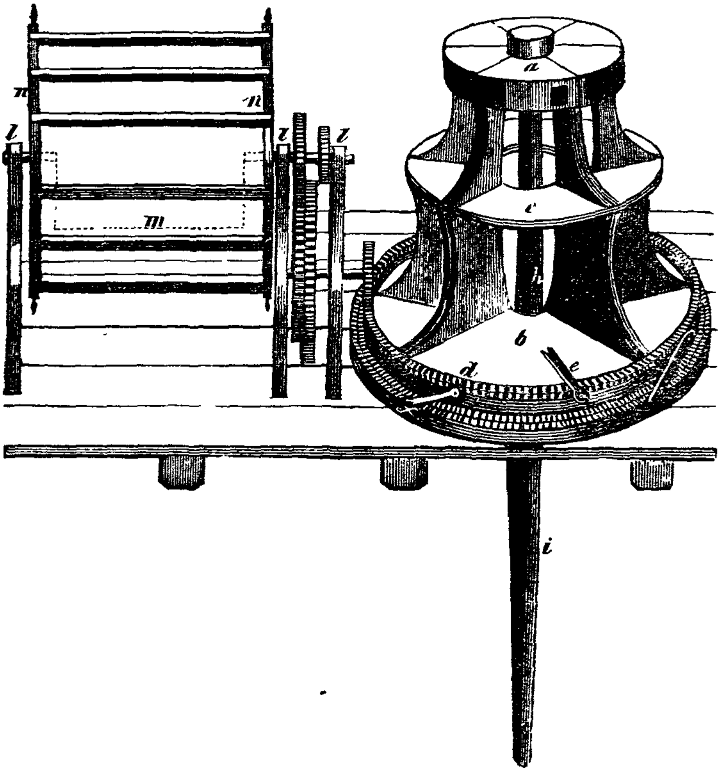
CAOUTCHOUC. A soft, dense, elastic, resinous substance, usually called India rubber, but sometimes very improperly elastic *gum*. It is obtained from the milky juice of several plants, the chief of which are the Jatropha elastica, and Urceola elastica. The juice, which is obtained by incision, is received in successive coatings on pieces of clay, and dried by the sun, or a fire made from dried leaves: as fast as one layer is dried, another is added, until it obtains the required thickness, when the clay mould is broken, and the tough leather-like substance taken out. The wonderful elasticity of this substance, and its resistance to water, has of late years brought it into extensive use for making waterproof garments, besides many other purposes. Its solvents are ether, volatile oils, and petroleum. The ether, however, must be washed with water repeatedly, when it dissolves it completely. Pelletier recommends the caoutchouc to be boiled in water for an hour, then to be cut into thin shreds, then boiled again, and afterwards put into rectified sulphuric ether in a vessel closely stopped. Berneard considers the nitrous ether as preferable. When this solution is spread upon any object, the ether quickly evaporates, and leaves the surface perfectly covered with the elastic resin. A solution of caoutchouc in five times its weight of oil of turpentine, and this solution dissolved in eight times its weight of drying linseed oil, is said to form the varnish of air balloons.

Caoutchouc may be formed into various articles without undergoing the process of solution. If it be cut into a uniform slip of a proper thickness, and wound spirally round a glass or metal rod, so that the edges shall be in close contact, and in this state be boiled for some time, the edges will adhere so as to form a tube. Pieces may be firmly united by merely heating their edges and pressing them together. Within these few years Messrs. Hancock and Mackintosh have obtained several patents for various modes of applying this valuable substance, which are daily rising into notice. The patent caoutchouc pipes are formed of alternate layers of solid or dissolved caoutchouc and canvass, or other suitable medium, and by pressure united into very tough pipes of any required bore or strength, without any stitch or seam, the weakest of which it is said is capable of bearing a pressure of 600 lbs. per square inch.

CAPILLARY TUBES, in Physics, are very small pipes, whose canals or bores are exceedingly narrow, their usual diameter not exceeding one-twentieth or one-thirtieth of an inch, and in some cases being made so small as to be scarcely perceptible. One of the most singular phenomena of these tubes is, that if they are left open at both ends, and one end immersed in water, the water will rise in the tube to a considerable height above the surface of that into which they are immersed, the height being inversely as the diameters of the tubes. Different fluids, however, attain different heights, and quicksilver does not rise, but, on the contrary, stands higher outside the tube than within. Various hypotheses have been invented to account for this ascent of fluids: at the present day it is attributed to a species of attraction, supposed to exist between the fluid and the tubes, and which is hence denominated capillary attraction.

CAPSTAN. A machine employed in large vessels, principally for "heaving up or weighing" the anchor. It consists of a drum or barrel, revolving upon an upright spindle, and having holes cut in the upper part or drum head, to receive the ends of a series of horizontal levers, named capstan bars. The cable, or, in very large vessels, a smaller rope, called the messenger, attached to the cable, is wound two or three times round the barrel, and as the capstan is turned round by a portion of the crew distributed at the capstan bars, another portion of them take in the slack of the cable or messenger, as it is unwound off the barrel of the capstan. The capstan is superior to the windlass in point of expedition, owing to the circumstance of the latter requiring the levers to be shifted into fresh holes four times in each revolution; and more men can also be employed at the capstan bars than at the hand-spikes of a windlass; but the men exert their strength more effectually at the windlass than at the capstan, since in the latter case they are employed to draw horizontally, when they exert a force of about 35 lbs. only, but at the windlass they may apply their whole weight at the extremity of the lever, and the average weight of a man is about 150, or more than four times his power of traction. In Hawkes' Patent Capstan, which we are about to describe, is combined the advantageous action of the windlass, with the continuous movement of the capstan; and the power or velocity may be varied according to circumstances. The engraving on the next page represents the patent capstan complete for one deck. *a* is the drum head of cast iron, with holes for the insertion of the capstan bars in the ordinary way, if from any cause that mode of turning the capstan should be preferred; *b* is the paul head, round the periphery of which are ranged ten pauls, five of which are in operation at a time, as that shown at *d*; the other five are kept turned up in readiness for use when the motion of the capstan is reversed. Each paul has two clips, which take into two teeth at the same time at every half inch of the revolution. The inner circle of teeth is for one set of pauls, and the outer circle for the other set, the notches being in contrary directions; both circles are inclosed within the paul-rim *f*. The barrel is composed of a number of projecting ribs named *whelps*, having a projection *c* in the middle, which divides the barrel into two parts; the upper portion is of a smaller diameter than the lower, so that by shifting the cable from the lower to the upper part of the barrel, an increase of power is obtained. In the figure the capstan is represented divided into six sections; but the number of these sections may be

varied according to the size and weight of the capstan; the divisions are made vertically through the whole length of the capstan, dividing also the whelps, the plates of which being strongly bolted together, unite it into one firm and compact body, and admit of its being easily disunited and removed. *h* is the central shaft of wrought iron, made square, except at the bearings, which are properly turned. *l l l* are three iron standards for supporting the gearing, which gives motion to the capstan, and may be worked either by means of a winch or crank, as shown by the dotted lines at *m*, or by means of capstan bars, supported horizontally in holes at the circumference of two vertical wheels *n n* fixed on the same axle as the crank; the circumference of these wheels being scored in a proper manner for allowing the bars to be dropped in and secured by pins, and to be quickly removed at pleasure. The bars when secured



in the rims of the wheels *n n*, form a kind of drum or reel, the men on one side of which lay hold of the bars and pull upwards, and those on the other side pull downwards either with their hands, or by stepping on the bars one after another as they revolve, and thus weigh down. The shaft which carries the wheels *n n* bears also two pinions, one of which is shown in gear with the smallest circle of a double cogged wheel; and on the same shaft as the latter is placed a pinion, which takes into the circle of cogs fixed on the upper surface of the paul-head, and causes it to revolve: if the small pinion is brought into gear with the large wheel, a great addition of power is gained; and according as the one or the other set of the wheels, and as the larger or smaller of the barrels of the capstan, are employed, the power admits of several variations to suit different circumstances.

CARABINE, or CARBINE. A fire-arm, something like a small musket; it is usually borne by cavalry soldiers, slung by a belt over the left shoulder.

CARAWAY. A plant much cultivated, particularly in Essex, for its seed, which is greatly esteemed for its agreeable flavour, pungent warmth, and medicinal properties. By distillation it affords an odoriferous essential oil, which is much used in white soap, and therewith constitutes the article termed Windsor soap.

CARBON. The name given in the modern chemical nomenclature to a simple combustible, which constitutes a large portion of all animal and vegetable substances, and which is found in the greatest state of purity in the diamond, which is composed solely of it. Carbon unites with all the simple combustibles, and with azote, forming a series of important compounds. From its affinity for oxygen, it is employed for disoxygenating metallic oxides, and restoring their bases to a metallic state. With iron it forms steel and plumbago; and with copper it likewise forms a carburet. In the state in which it is commonly obtained it is termed charcoal, which see.

CARBONATES. Compounds of carbonic acid with salifiable bases composed either of one prime of acid and one of base, or one of acid to two of base. The former set of compounds are termed carbonates, and the latter bicarbonates.

CARBONIC ACID. An acid composed of oxygen and carbon. It abounds in great quantities in nature, and appears to be produced in a variety of circumstances. It composes forty-four hundredths of the weight of limestone, marble, and other natural specimens of calcareous earth, from which it may be extricated by the simple application of heat, or by the superior affinity of some other acid, most acids having a stronger action on bodies than this. It is composed of 72 parts of oxygen, and 28 of carbon, and its spec. grav. is 1·5236, that of atmospheric air being 1·0000. See AERATED WATERS.

CARBONIC OXIDE. A gaseous compound of oxygen and carbon, consisting by weight of 75 of the former, and 100 of the latter. Its spec. grav. is 0.9569. Carbonic oxide may be procured by subjecting to a strong heat in a retort or gun-barrel, a mixture of an earthy carbonate and metallic filings; the most convenient mixture is equal parts of dry chalk, and iron or zinc filings; it is given out also in large quantities from brick kilns, and may be seen burning with a dark blue flame. It is, when respired, fatal to animal life.

CARBUNCLE. An elegant gem whose colour is deep red, with an admixture of scarlet. It is usually found pure and faultless, and is of the same degree of hardness as sapphire. It is naturally of an angular figure, and is found adhering by its base to a heavy and ferruginous stone of the emery kind. It bears the fire unaltered; is found only in the East Indies, and there but rarely.

CARBURETS. Combinations of carbon with any of the simple substances.

CARDS. In the manufactures of cotton and wool, an instrument used for preparing those substances for being spun into thread, by strengthening the fibres, and rendering them parallel to each other. They are a species of brush, composed of wires stuck through strips of leather, and not standing erect, but inclined to the surface of the leather, and are used by filling the teeth of one card with the cotton or wool, and drawing another card along in a direction against the inclination of the teeth, by which means the fibres are drawn out in a parallel direction, and transferred from the one card to the other. Carding was originally performed by hand with sheets of cards nailed upon thin boards, which were drawn against each other. Stock cards were subsequently introduced: in these one card was nailed to an inclined post or bend, and a hand card drawn over it; but at present the cards are generally arranged upon cylinders, which revolve either against other card cylinders, or against fixed cards. Cards are fastened upon the cylinders either in parallel strips in the line of the axis, or they form a continuous spiral band covering the entire surface of the cylinder. From the immense number of cards required in cotton mills, the manufacture is one of great extent and importance, and several very curious machines have been invented for facilitating the processes, though they have

not yet come into common use. In general the leather is pierced by machinery at the manufacturers', who send it out to the cottagers, together with the wire, which they cut and bend into form, and afterwards insert in the holes of the leather. The workman first takes a skein or bundle of wire, consisting of 30 or 40 wires, and placing them against a gauge, cuts the whole at one operation to the same length, by means of a strong pair of shears. The wires thus cut are then placed in another gauge, and a piece of steel, of the same width as the two legs are to be asunder, is then pressed across the middle of them, and the ends of the wires, first on one side, and then the other, are turned up against the sides of the bridge, forming the wire into a staple like this ; they are then given the knee bend, which brings them into this shape , by an ingenious machine kept in motion by a weight, like a roasting jack, after which they are inserted in the leathers by women or children.

CARMINE. A very bright crimson pigment, obtained by precipitating the colouring matter of cochineal. The preparation is as follows:—Take 4 ounces of cochineal, finely pulverized, which pour into 4 quarts of rain or distilled water, boiled previously in a pewter kettle, and boil the whole for six minutes, adding, during the boiling, 2 drachms of pulverized crystals of tartar. Eight scruples of Roman alum, in powder, must then be added, and the whole be kept on the fire one minute longer. As soon as the gross powder has subsided, and the decoction become clear, decant it into large cylindrical glasses covered over, and keep it undisturbed till a fine powder is observed to have settled at the bottom. Then pour off the liquor from this powder, which is to be gradually dried. From the liquor still coloured, the rest of the colouring matter may be separated by the solution of tin, when it yields a carmine little inferior to the former.

CARPENTRY is the art of cutting out, framing, and joining large pieces of wood to be used in building. The only difference between Carpentry and Joinery is, that whilst the former includes the larger and rougher description of work, which is essential to the construction and stability of an edifice, the latter term comprehends the exterior finishing and ornamental wood-work. To enter into a detailed account of the numerous tools used in Carpentry, and the processes of forming, by their application, the almost illimitable variety of matters that are comprehended in constructive carpentry, would of course require a volume to itself; and as the subject is foreign to the leading objects of this work, we shall under this head confine ourselves to some general observations of a practical nature, alike useful to the engineer as well as the carpenter. With regard to the tenacity or strength of wood, it has been found by Muschenbroëk and other eminent experimentalists, first, that the wood which surrounds immediately the pith or heart of the tree is the weakest, and that this weakness is greater as the tree is older. It is of importance that this fact be known, as a common notion exists of a contrary nature. Secondly, the fibres next to the bark, commonly called the white or blea, are also weaker than the rest; and the wood gradually increases in strength as it recedes from the centre to the blea. Thirdly, the wood is stronger in the middle of the trunk than at the springing of the branches, or at the root; and the wood forming a branch is weaker than that of the trunk. Fourthly, the wood on the northern sides of all trees that grow in Europe is the weakest, while that on the south-eastern side is the strongest; this difference is most remarkable in hedge-row trees, and such as grow singly. The heart of a tree never lies in its centre, but always towards its northern side, and the annual coats of wood are thinner on that side. In conformity with this, it is a general opinion of carpenters that timber is stronger in proportion to the thickness of its annual plates. The trachea, or air vessels, being the same in diameter and number of rows in trees of the same species, occasion the visible separation between the annual plates; for which reason, when these are thicker, they contain a greater portion of the simple ligneous fibres. Fifthly, all woods are most tenacious whilst green, but after the trees are felled, that tenacity is considerably diminished by their drying. By the experiments of Muschenbroëk, it appears that the absolute strengths of a square inch of the following different kinds of wood are as stated

Locust	20,100	Pomegranate	9,750
Jujeb	18,500	Lemon	9,250
Beech and Oak	17,300	Tamarind	8,750
Orange	15,500	Fir	8,330
Alder	13,900	Walnut	8,130
Elm	13,200	Pitch pine	7,650
Mulberry and Willow	12,500	Quince	6,750
Ash	12,000	Cypress	6,000
Plum	11,800	Poplar	5,500
Elder	10,000	Cedar	4,800

The woods mentioned were all formed into slips of uniform dimensions, and as much cut away from each, as to form a parallelopiped of one-fifth of an inch, that is, one-twenty-fifth of a square inch in section; and the weights which were required to tear these asunder, formed the data of the above calculations. Muschenbroëk gives a very minute detail of his experiments on the ash and walnut, in which he states the weights required to tear asunder slips taken from the four sides of these trees, and on each side in a regular progression from the centre to the circumference. The numbers in the foregoing, corresponding with these two woods, may be considered, therefore, as the average of more than fifty trials of each. He mentions, also, that all the other numbers were calculated with the same care. For these reasons some confidence may be placed in the results, though they carry the degree of tenacity considerably higher than those enumerated by some other writers. Pitot and Parent state, that a weight of 60 lbs. will just tear asunder a square line of sound oak, but that it will bear 50 lbs. with safety. This gives 8640 for the greatest strength of a square inch, or rather less than one-half of Muschenbroëk's estimate; but the latter is, we think, the most entitled to confidence, as the experiments were made upon greater masses of the material. It should, however, be observed, that two-thirds of the actual weight which may be sustained by a body, will greatly impair the strength after a considerable time, and that one-half the absolute tenacity indicated by experiment, should be the *utmost* that an engineer should calculate upon in his constructions. Woods of the same denomination often differ greatly in their tenacity; those with a very straight fibre suffer less injury from a load that is insufficient to break them immediately. Mr. Emerson mentions the following as the loads which may be safely suspended to an inch square of the several bodies hereafter enumerated; but the term *safely* can hardly apply to the four first-named bodies.

	lbs.		lbs.
Iron	76,400	Red fir, holly, elder, plane, and crab	5,000
Brass	35,600	Cherry and hazel	4,760
Hempen rope	19,600	Alder, asp, birch, and willow	4,290
Ivory	15,700	Lead	450
Oak, box, and yew	7,850	Freestone	914
Elm, ash, and beech	6,070		
Walnut and plum	5,360		

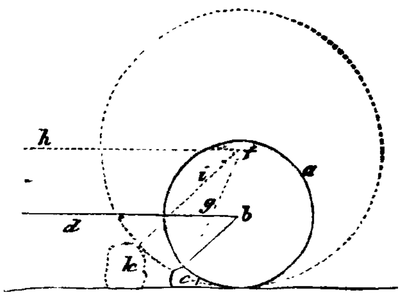
The same ingenious author has laid down as a practical rule, that a cylinder of one inch diameter will carry, when loaded to one-fourth of its absolute strength, as follows:—iron, 135 cwt.; good rope, 22 cwt.; oak, 14 cwt.; and fir, 9 cwt. Parent has shown that the force required to crush a body is nearly equal to that which will tear it asunder. This may be an approximation to the truth as respects woods, but it will not apply to any other bodies. Glass, for instance, will carry a hundred times more on it than oak in this way, but will not bear suspended above four or five times as much. Oak will suspend a great deal more than fir, but fir will carry twice as much as a pillar. Some woods which are very soft, and consequently yield to pressure, possess very strong fibres, and will resist a longitudinal strain. The softness of texture is chiefly owing to the crooked nature of their fibres, and to the existence of considerable vacuities between each fibre, so that they are more easily bent in a lateral direction and crushed. In all cases where the fibres lie oblique to the strain,

the strength is considerably diminished, which may be ascribed to the circumstance, that the parts in such case slide on each other, and the connecting force of the cementing matter is for that reason easier overcome. The strain which most commonly acts on materials of any nature, is that which tends to break them in a transverse direction. For the results derived from experiment in strains of this nature, we must refer the reader to the article STRENGTH OF MATERIALS; but the complete investigation of the resistance of materials, according to the direction and situation of the forces applied, would require a volume. The reader who wishes for full information on this subject, cannot do better than consult Mr. Barlow's valuable *Essay on the Strength and Stress of Timber*. Some excellent practical rules on this important subject will, however, be found in *The New Practical Builder*, by Nicholson, and in the works of Banks, Emerson, and Roberson.

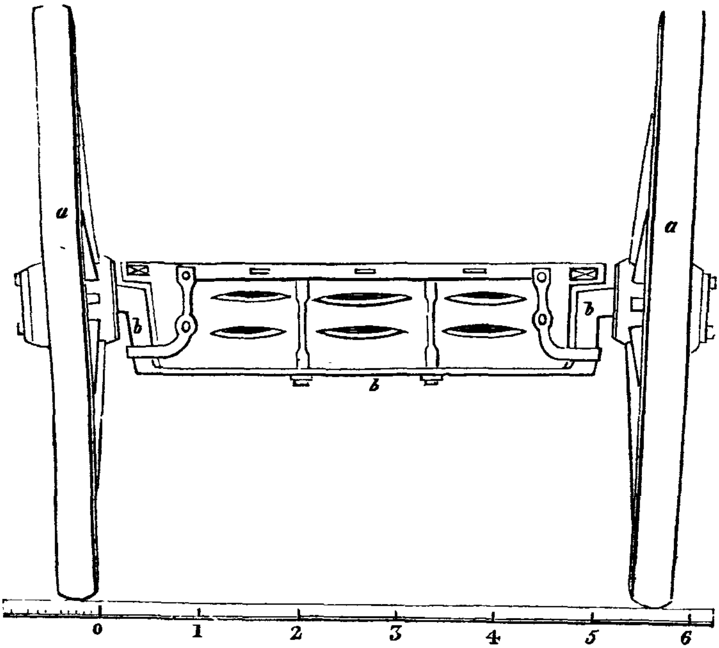
CARPET is a sort of stuff wrought with the needle, or on a loom, and forms the ordinary furniture of a house, being commonly laid upon the floor. The Persian and Turkey carpets have hitherto been in the greatest esteem, but some of the manufacturers of France and Great Britain are making rapid advances in imitating them, to which they are, in some respects, superior. A splendid example of this fine spirit of rivalry amongst our own countrymen is now exhibiting at the Museum of National Manufactures and of the Mechanical Arts, in Leicester Square, London. The carpet measures 8 yards by 6, and is called Scoto-Persian by the manufacturers, Messrs. Deans, of Stewarton, in Ayrshire. In the usual mode of weaving carpets, the design or pattern is traced in its proper colours on cartoons, tied before the workman, who looks at them every moment, because every stitch is marked upon them as it is to be in his work. By this means he always knows what colours and shades he is to use, and how many stitches of the same colour. In this he is assisted by squares, into which the whole design is divided; each square is divided into ten vertical lines, corresponding with the parcels of ten threads of the warp; and besides, each square is ruled with ten horizontal lines crossing the vertical lines at right angles. The workman having placed his spindles of thread near him, begins to work on the first horizontal line of one of the squares. The lines marked in the cartoon are not traced on the warp, because an iron wire, which is longer than the width of a parcel of ten threads, supplies the place of a cross line. This wire is managed by a crook at one end, at the workman's right hand; towards the other end it is flatted into a sort of knife with a back and edge, and grows wider at the point. The weaver fixes his wire horizontally on the warp, by twisting some turns of a suitable thread of the woof around it, which he passes forward and backward behind a fore thread of the warp, and then behind the opposite thread, drawing them in their turn by their leashes. Afterwards, he brings the woof-thread round the wire in order to begin again to thrust it into the warp. He continues in this manner to cover the iron rod or wire, and to fill up a line to the tenth thread of the warp. He is at liberty either to stop here, or to go on with the same cross line in the next division, according as he passes the thread of the woof round the iron wire, and into the warp, the threads of which he causes to cross one another at every instant; when he comes to the end of the line he takes care to strike in the woof he has used. This row of stitches is again closed and levelled, and in the same manner the weaver proceeds; then with his left hand he lays a strong pair of shears along the finished line, cuts off the loose hairs, and thus forms a row of tufts perfectly even, which, together with those before and after it, form the shag. Thus the workman follows, stitch for stitch and colour for colour, the plan of his pattern, which he is attempting to imitate; and he paints magnificently without having he least notion of painting or drawing.

CARRIAGE. A vehicle for the transport of persons and goods by land. Although the varieties of carriages are very great, yet they may be ranged under two heads, viz. sledges, or carriages without wheels, and wheeled carriages. The earliest carriages were doubtless of the first class, or without wheels; and although they are now very generally superseded by carriages mounted upon wheels, and indeed have become nearly obsolete in this country, yet they are

still extensively used in the more northern parts of Europe, where the ground is for a considerable portion of the year covered with snow, and the rivers frozen over so as to allow carriages to travel upon them. In these cases sledges are found superior to wheel carriages, as the friction upon the surface of the snow or ice is small, and as, from the greater extent of bearing surface, they do not sink so deep as wheel carriages, in which the whole weight presses upon two, or at most, four points. The motion is also found to be much more easy, as from their length of bearing they do not rise and fall with every slight inequality in the roads, in the manner of wheel carriages. But for general purposes, and on roads composed of rough materials, which offer great resistance to bodies sliding over them, it is found highly advantageous to place the carriages upon wheels, as by this means the sliding motion is converted into a rolling motion, and the rubbing surfaces, when the friction takes place, are reduced in the proportion of the diameter of the wheel to that of its axle, and the friction is still further reduced by the rubbing surfaces being polished, and admitting of lubrication, which tends materially to diminish friction. The friction being diminished in proportion to the difference between the diameters of the wheels and the axles, it is evidently advantageous to employ wheels of large diameter, which are also beneficial in another respect, as they experience less resistance from the inequalities of the surface over which they roll, as the leverage to which the power of the horse is applied, is as the diameter of the wheel; and as any obstacle on a road will sooner come in contact with a large wheel than with a small one, in consequence of the curvature of the former being flatter than that of the latter, so the power by which the wheel is drawn over the obstacle is exerted through a greater space with the large than with the small one. We shall endeavour further to explain this by a little diagram. Let the circle *a* represent a small wheel, whose axle is at *b*, and *c* a stone lying in the road, over which the wheel is to pass; and the dotted circle to represent a large wheel, whose centre is at *f*; now the obstacle *k* is already in contact with the large wheel, but the small wheel has not yet arrived at it: the horse would therefore move through a greater space in bringing the centre of the large wheel perpendicularly over the obstacle, than in bringing the centre of the small wheel over the object after it had come in contact with the periphery; thus the horse exerts more power, or what is the same, exerts the same power through a greater space with the large wheel than with the small one. And again, as the angle *k f h*, at which the obstacle *k* interrupts the large wheel, is the same as the angle *c b d*, at which the obstacle *c* interrupts the small wheel, the same force which will draw the small wheel over the obstacle *c*, will, by the increased leverage, draw the large wheel over the obstacle *k*. The advantages above attributed to large wheels over small ones are not merely theoretical, but have been confirmed in a variety of instances in practice. We therefore insert the diagram on the following page, exhibiting a method of applying hind wheels of larger diameter than ordinary to waggons, without carrying the floor higher than usual. *a a* represents the hind wheels; *b b* the bended axletree, of a crank form, passing under the bed of the carriage, which lies between the two extremities of the axletree, and permits the floor of the carriage to lie close to the upper side of the axletree, the floor being usually as much above the latter as the thickness or depth of the bed. The modes by which carriages are or have been propelled are various—as the force of animals, of wind, of men, exerted upon machinery contained within the carriage, and that of steam. Carriages propelled by wind acting upon sails are not common for land travelling, although such have been



constructed; but in some parts of Holland, boats mounted upon long skids are frequently employed for sailing over the ice, and have sometimes been known



to go at the rate of eighteen miles per hour. In 1826 a patent was obtained by Col. Viney and G. Pocock, for a carriage, to be impelled by the force of the wind acting upon one or more kites attached to the carriage, which they denominated the "Charvolant." It is represented in *Fig.* 2 in the engraving on the following page. The kite, *a*, *Fig.* 1, is jointed in the middle, that it may be folded up, and carried or stowed away with greater facility. *b b b b* are four cords for regulating the position of the kite, and to assist the steerage; they are brought together by passing through the dead eye *c*, whence they proceed to the carriage, where they are regulated to the proper lengths by the persons therein. By shortening the cords on the right-hand side of the kite, the car may be turned to the right, and by shortening the left-hand cords it will be turned to the left. But the charvolant, by the cross handle *e* and stem *e f*, which acts on the axis of the fore wheels by means of an endless band or cord passing about a pulley *f* fixed on the lower end of the stem *e f*, and the pulley *g* fixed on to the bed of the axletree of the fore wheels. The machine is stopped, or its motion retarded by the drag *k*, which is attached to the perch by a spring to keep it off the ground till it is required to retard the motion or to stop the carriage, when the fluke end is pressed into the earth by the lever *h* acting on the connecting piece *i*. The patentees several times exhibited a carriage similar to the above, in Hyde Park, and, we believe, performed a journey from Southampton to London with it, but we do not recollect the particulars. The scheme is not altogether original. Dr. Franklin employed kites to assist swimmers, and was of opinion that with such aid a man might swim across the Channel from Dover to Calais. Attempts have also been made before the present to move both boats and cars by the same means; but we believe the present is the first attempt to trim or regulate the position of the kite according to the direction in which the carriage is to move.

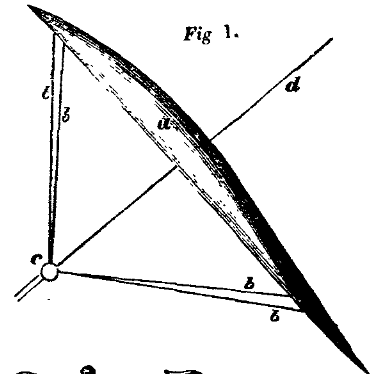


Fig 1.

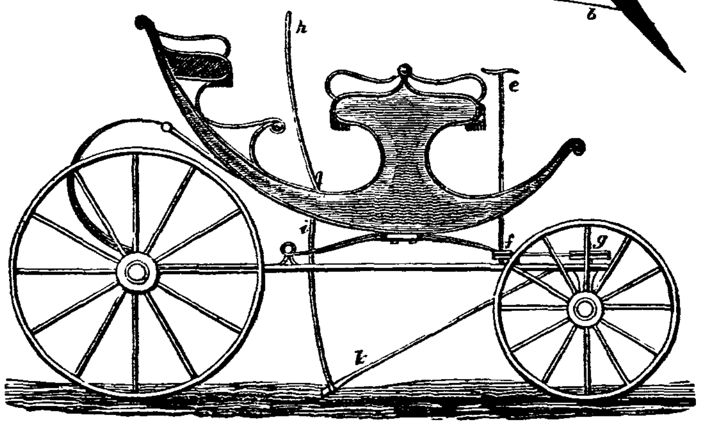
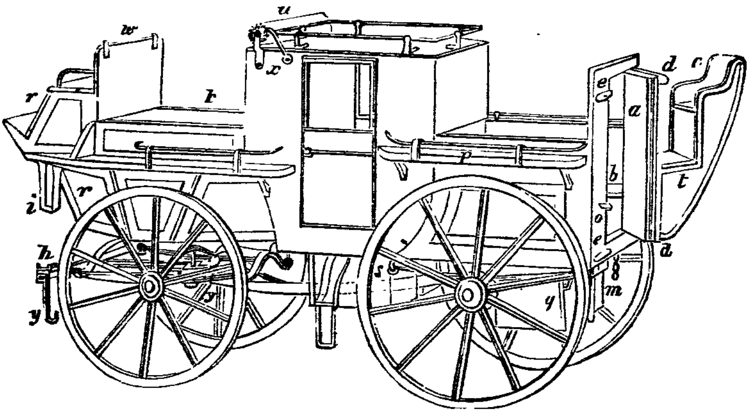


Fig. 2.

In no class of carriages does this country so much excel all other nations as in the stage coaches, which, for beauty, compactness, lightness, strength, and easy draught, are far superior to the public vehicles of any other country. In a nation so eminently commercial, where dispatch and punctuality are of the first necessity in conducting all transactions, every thing which tends to advance the means of communication becomes an object of consideration; and numerous improvements have of late years therefore been introduced in the structure and arrangement of our stage coaches. The engraving in the following page represents a model of an improved stage coach, by Mr. Skinner, for which he was presented with the sum of thirty guineas by the Society of Arts. The lowering of the centre of gravity, by removing the heavy luggage and outside passengers from the roof of the carriage; the convenient accommodation of the latter; the adoption of high fore-wheels to ease the draught; and several minor conveniences; will be found to have been duly attended to, and to be combined in the model of which the following is a description. The engraving gives a perspective view of the vehicle. The front wheels are 5 feet 9 inches in diameter. The inside and outside passengers are seated on the same level, the floor being as near to the axletree as the play of the springs will admit. *a* is the door through which the hind passengers get up, the seats being situated as shown at *b*; *c* is a seat for the guard, attached to the door *a*; *d d* iron bars attached to the top and bottom of the door, and projecting enough to be firmly held by turn buckles *e e*; the steps *g h* and *i*, serve for the front passengers and coachman to ascend by; the passengers step upon the boards *j j* on either side, and over the side rails into the compartment *k*; the steps *l m n o* serve for ascending the hind part of the coach; *p p* boards on each side over the hind wheels; there are similar ones *j j* over the front wheels, which have iron rails

to hold small luggage. To allow of locking the front wheels, the floor is narrowed in the manner delineated; *q* is the hind boot; *r r* the front boot; *s* boxes opening in the floor of the coach; *t* and *v* boxes opening in the guard's seat; *u* a roll of leather to cover the front passengers; it has a slip of iron along its



front, which catches on to the hooks *w w;* it is wound up and held tight by a ratchet wheel and pall *x; y* the locking pin, which plays through the axletree; the locking plate is under the floor and above the springs. There are five springs in front, and five at the back; two across each axletree, four across the coach answering to them, and two more, one over each axletree, and rubbing on them.

The following engraving represents a stage coach of a very novel appearance, invented by Mr. P. Birt, of the Strand, and distinguished by an improved method of yoking the horses, and also by a drag which can be put into action at pleasure, without any person descending for that purpose. The inside passengers occupy the seats at *i n s*, which are at a higher level than those for the

outside passengers at *o u t*. There are three doors, one opening into the inside, behind the seat *n*, and two opening into the outside at *d d*. The receptacle for the luggage is at the bottom *c c*; *f* is the coachman's seat, where he is provided with the means of putting the drag in action at pleasure, by means of the

lever *g*, the extremity of which is connected by a rope or chain to the skid iron, and the latter is supported by a spring arm *j*, which is fixed to the axletree or the hind wheels. The usual method of yoking the horses to a coach, is to attach the two ends of the traces to *two fixed points* on the long front splinter-

Fig. 3.

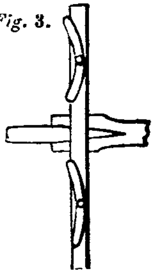
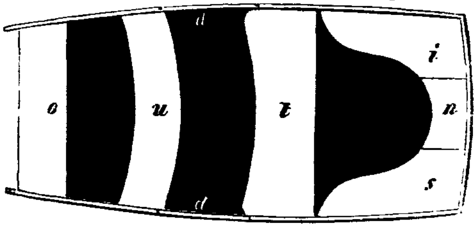


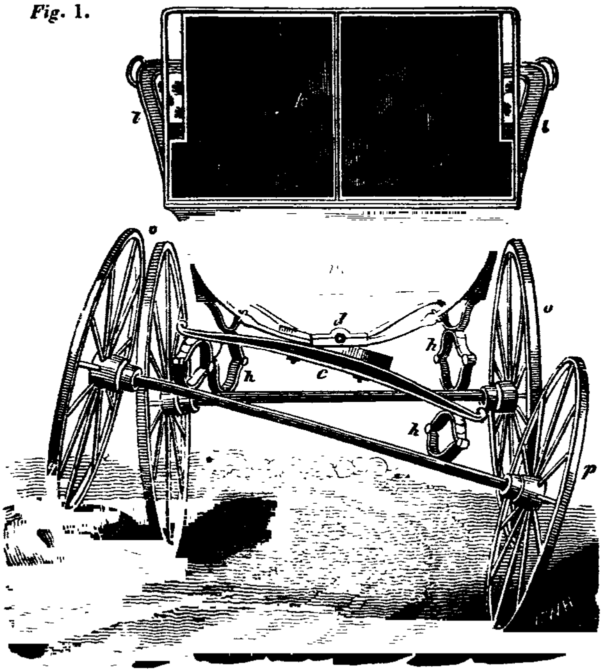
Fig. 2.



bar. In this way, if the traces are not exactly of a length, the horse pulls only on one side when going in a straight line, and invariably so when making a curve in the road; the traces are, in consequence, subject to double the strain, and the horses have all the work thrown upon one shoulder, instead of it being equalized on both. To remedy this disadvantage Mr. Birt fixes two bent elastic pieces to the splinter-bar, as shown in *Fig.* 3, which turn upon central pivots; and the traces being attached to the extremities of these elastic bars, the pull is made from a single point, like that of the leaders in a four-horsed coach. The advantage derived from this alteration is, greater freedom to the action of the horses, and a better direction of their power; the elastic bars likewise prevent a great deal of unpleasant jolting, usually communicated to the carriage by the motion of the horses.

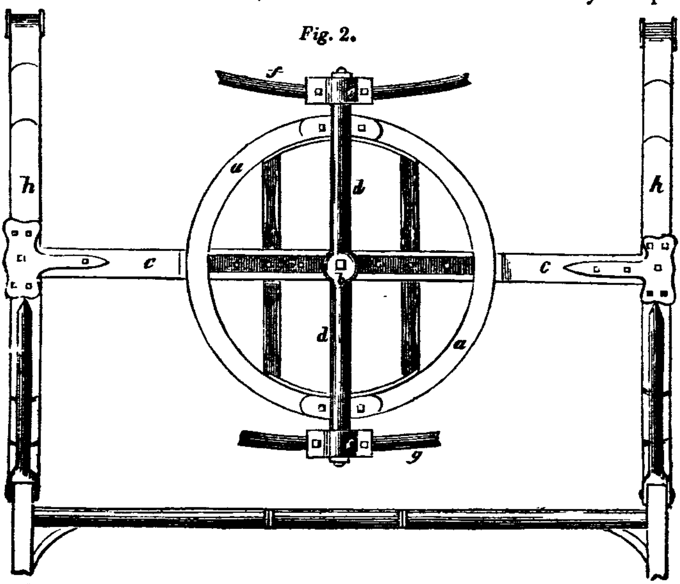
The annexed engraving represents a four-wheeled carriage, invented by Mr.

Fig. 1.



Fuller, of Bath, so constructed as to prevent the upsetting by those irregularities in the road which are sufficient to overturn carriages of the usual construction, and, at the same time, to lessen considerably the unpleasant jolting motion arising from the same cause. The construction may be described as follows:— Immediately over the axles of the fore wheels is placed a bar *c c* (which the inventor calls the bed of the axle); this bar is attached to the axle by the springs

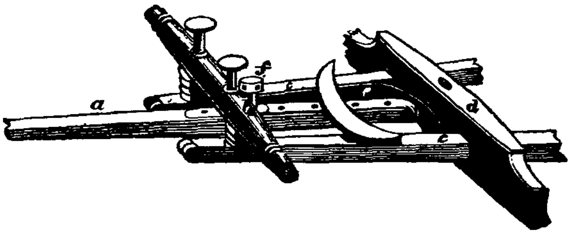
Fig. 2.



h h. On this bar is placed the locking wheel *a a*, which turns on the pivot *b*, and is supported on the bar and frame-work as shown in *Fig.* 2. To the locking wheel is firmly fixed the horizontal bar *d d*, at right angles to the axle-bed, when the carriage is going straight forward. The ends of this cross-bar are turned and fitted into the plummer block *c c*, which are attached by means of the connecting pieces *f f* and *g g*, to the fore part of the carriage as represented in *Fig.* 1. This permits the axle of the fore wheels, with the locking wheel, to take an inclined position, while the body of the carriage remains level; and it will be seen from the carriage represented in *Fig.* 1, (which is a front view,) that the axle of the fore wheels *p q*, with the locking wheel and its attachments, is inclined considerably by the wheel *q* passing over an elevation in the road, while the body of the carriage remains horizontal, and its weight is equally supported by both the wheels, instead of being all thrown on the lower wheel, as would be the case were it not permitted to turn on the pivots of the bar *d*. The other parts of the carriage are not different from those in common use, and therefore need not be particularly described. *o o* are the hind wheels; *l l* part of the seats; *k* the dashing-iron and leather, and *m* the foot-board.

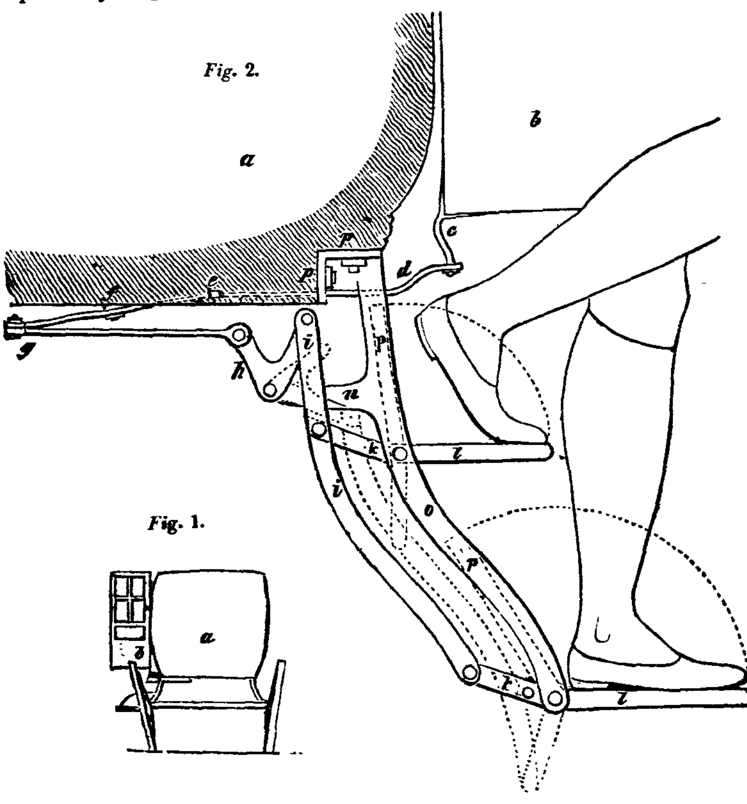
The engraving on the following page represents a method of firmly fixing the poles to carriages, and, when required, of readily releasing them, great inconvenience being frequently experienced from the poles sticking fast in wet weather when fitted on the common plan, and being also subject to premature destruction in those parts. *a* is the pole of the carriage; *b* the splinter bar; *c c* the fetchels; *d* part of the wooden axletree. An iron frame *e e* is fixed between the fetchels; in the front of this iron frame there is a proper aperture to receive the tapered part of the carriage pole, and another at the back, of less dimensions, to receive the extreme end, which is shod with an iron bolt for that purpose; this bolt or pin is fixed on to the extremity of the pole by two long straps, which clasp the

top and the bottom, and have bolts passing through both. When the pole is inserted into its place, it is secured there by turning the screw *f*, which forces



two iron wedges into recesses made in the frame, from whence they cannot be withdrawn, or the pole detached, but by turning the pole the reverse way.

A patent was obtained in 1825 by Mr. Corbet, of Glasgow, for an improvement upon the steps of carriages; which is applicable to coaches generally, but is peculiarly adapted to such, the proprietors of which do not employ a footman



to open and shut the door and steps, as the act of opening the door causes the steps to open out, and that of shutting it shuts the steps up again. For this reason the invention may be found of great convenience to medical and other professional gentlemen. In the above engraving, *Fig.* 1 is intended to

represent the back view of a coach, on one side of which the steps and door are both open, and on the other side are both shut. *Fig.* 2 gives a side view of the steps, only on a larger scale, and will, we trust, enable the reader to understand their construction. At *a* is the coach body; *b* a part of the coach door open; *c* is a bent iron fixed to the bottom of the door, connected to a curved rod *d*, at the extremity of which is a joint *e* attaching it to the lever *f*, which moves upon a fulcrum in the middle; at *g* is another joint, by which and an intermediate rod it is attached to one of the horns of the crank *h*; the other horn of this crank is connected by a joint to the long curved lever *i i*, which gives motion to the short levers *k k*, and these last being in one piece with the steps *l l*, they move together. The long curved bar *o*, (of which there are two, one on each side of the steps,) and its short branch *n* are fixtures, being bolted to the body of the carriage *p p*. The reader having noticed the train and connexion of the levers just mentioned, will readily perceive that the act of shutting the door of the carriage will cause the lever *f* to assume another angle, by which the crank *h*, and consequently the bar *i i*, will be thrown into the position shown by the dotted lines; and that it necessarily follows the steps will be forced into the situation shown by the dotted lines at *l l*.

CARNELIAN is a sub-species of calcedony. Its colours are white yellow, brown, and red. It has a conchoidal fracture, and a spec. grav. of 2.6. It is semi-transparent, and has a glistening lustre. It is found in the channels of torrents in India, in nodules of a blackish olive, passing into grey. After exposure for some weeks to the sun, they are subjected to heat in earthen pots, whence proceed the lively colours for which they are valued in jewellery.

CARRONADE. A short piece of ordnance, intended principally for close combat at sea.

CARTHAMUS, Safflower, or Bastard Saffron. Watery menstrua take up the yellow, and leave the red colour, which may afterwards be extracted by alcohol, or by a weak solution of alkali; such particularly are the saffron coloured flowers of carthamus. These, after the yellow matter has been extracted by water, are said to give a tincture to ley, from which, on standing at rest for some time, a deep red fecula subsides, called safflower; and from the countries whence it is commonly brought to us, Spanish red and China lake. The pigment impregnates alcohol with a beautiful red tincture, but communicates no colour to water. Rouge is prepared from carthamus. For this purpose the red colour is extracted by a solution of the sub-carbonate of soda, and precipitated by lemon juice, previously depurated by standing. This precipitate is dried on earthen plates, mixed with French chalk, reduced to a powder by means of the leaves of shave grass, triturated with it till they are both very fine, and then sifted. The fineness of the powder, and proportion of the precipitate, constitute the difference between the finer and the cheaper rouge. It is likewise spread very thin upon saucers, and sold in that state for dying. Carthamus is used for dying silk of a poppy, cherry, rose, or bright orange red.

CARTOON, or Carton. A design drawn on strong paper, to be afterwards chalked through, and transferred on the fresh plaster of a wall, to be painted in fresco. It is also used for a design coloured for working mosaic tapestry, carpets, &c. The word is from the Italian, *cartoni*, large paper, denoting many sheets of paper pasted on canvass, on which large designs are made, whether coloured or with chalks only. The most celebrated performances of this kind are those by Raphael.

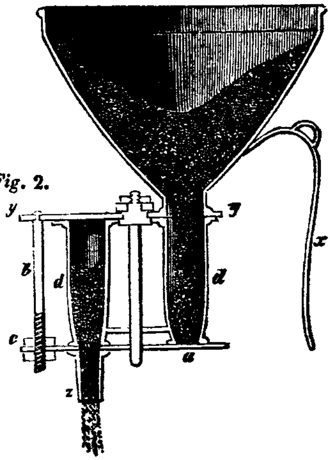
CARTOUCHE is a general term in the military art, applicable to a variety of projectiles contained in differently formed cases.

CARTRIDGE. A case containing a charge of powder for fire-arms. For pistols and muskets the case is made of strong paper manufactured for the purpose, and called therefore cartridge-paper, and the cartridges are called ball or blank cartridges, accordingly as they contain or not a ball or bullet, with the powder in the case. For cannon, the case for the powder is made of serge or flannel; but the Americans, during the last war, are said to have employed for

that purpose "*tea-lead*," similar to that used for lining tea-chests; the advantage of which is, that the guns do not require sponging, and that no ignited portions of the cartridge can remain in the chamber, from which most dreadful accidents sometimes happen. For cannon, the cartridges are always made up without the shot, between which and the cartridge, a wad made of old rope is placed in charging the cannon. The annexed engraving represents an ingenious and well-contrived machine, invented by W. Caffin, Esq., of Woolwich, for filling cartridges, but which, if constructed on a larger scale, may be applied to measure grain, seed, and all other articles that are estimated by strike measure. *Fig.* 1 represents a perspective view of the instrument, and *Fig.* 2 an elevation in section. The measures *d d* are fixed vertically in a circular plate *f* opposite to each other, with an axis between them, upon which they work between two other plates. On the top plate *y y* a hopper *w* is fixed, communicating alternately with the measures, and filling them; and on the opposite side, in the bottom plate *a*, is a hole with a spout *z*, through which the discharge takes place. The plates are framed together by three pillars *b b b*, having double adjusting nuts *c c* on each to regulate the distance of the plates. The measures are moved by a handle or lever *e*, the motion of which is limited by two pins *g g*, which, while it presents one under the hopper to receive, places the other immediately over the discharge hole for delivery, so that the two operations of filling and discharging, are going on at the same time. The bottom of each measure is contracted, to retard, in a small degree, the discharge, so as to secure one measure being filled before the other is emptied. A hole is cut in the top plate over the discharging measure, by which it may be ascertained that it is always perfectly filled, as well as that the whole of its contents are delivered; *x* is the hook by which the machine is supported. Some of these machines have been used a long time for filling cartridges, and a boy delivers with ease 12,500 measures daily, from one machine, in the most perfect and accurate manner, and supplies his hopper himself.

Fig. 1.

Fig. 2.



CARVING, in a general sense, is the art of cutting or fashioning a hard body by means of some sharp instrument; but in a more particular sense it is usually understood to be the art of cutting figures and designs in wood. A carver should possess some knowledge of drawing and modelling, in order that he may be able to copy from nature. A rough imitation of the object or design should first be modelled in clay by the fingers, and afterwards completed with the modelling tools. A mould is then to be made, and a cast taken from the model in plaster of Paris, as clay is difficult to preserve unless baked in a kiln. The mould is made in the following manner:—Plaster of Paris, which

easily mixes with water, should be made of the thickness of cream, and should be spread all over the model. When the plaster is set, the model should be removed, the clay carefully picked out, and a mould will be obtained, called a waste mould, which must be left in cold water for a quarter of an hour. When used as a cast, it should be rubbed over with a mixture of hog's lard and the droppings of sweet oil. The plaster of Paris is to be mixed as before, and poured into the mould, which afterwards should be knocked off with a chisel and mallet, by small pieces at a time; the design will then appear of the same form as that modelled in clay, which the carver may proceed to copy in any sort of wood, but lime-tree is the best suited to beginners. The tools used in carving are of various forms and sizes, and may be procured of good quality in the shops, ready made. The instruments used by sculptors for measuring the different parts of their work, particularly the heights and depths, may be very advantageously employed by the carver. Carving is an extremely fascinating employment, and the young artist of taste soon becomes astonished and delighted with the effect he produces by a few cuts of his chisel.

CASCABEL. The knot of metal behind the breech of a cannon; it serves as a handle to elevate or direct the piece, and likewise to sling and fasten it.

CASCADE. A steep fall of water from a higher to a lower place: cascades are both natural and artificial; those which fall with great noise are usually called cataracts, which see; also FOUNTAIN.

CASE. In printing, a large oblong frame, placed aslope, divided into several little square compartments, in each of which are kept a quantity of type or letters of the same kind, whence the compositor takes them as he requires them to compose his matter.

CASE-HARDENING is a term applied to the process of converting the external surface of articles or masses of iron into steel, with the view of combining the hardness of the latter with the toughness and comparative cheapness of the former. See IRON.

CASEMATES. Vaulted apartments of masonry made in the bastions of fortifications.

CASEMENT. A small window made to open or turn upon hinges.

CASERNS. A term frequently used synonymously with barracks, but which more strictly applies to the huts or lodgings of soldiers in the ramparts of fortified places.

CASE SHOT, or CANISTER SHOT. Tin canisters filled with small balls, which are discharged from cannon, and make sad havock with human life.

CASHEW-NUT. See ANACARDIUM.

CASK. A vessel of capacity, for holding both liquid and dry goods. See BARREL and COOPERING.

CASTING AND MOULDING. Under this head we shall give the art of taking impressions from sculptures, medals, and other delicate works of art; also the taking of casts from the face, and other natural objects. For the process of casting articles of metal in the large way, see FOUNDRY. To procure a cast from any figure, bust, medal, &c. it is necessary to obtain a mould, by pressing upon the thing to be copied some substance capable of being forced into all the cavities or hollows of the sculpture. When this mould is dry and hard, some substance, which will fill all the cavities of the mould, is poured into it: the form of the original from which the mould was taken, is now accurately represented. Moulding in any particular manner depends upon the form of the subject. When there are no projecting parts, but such as rectilineal angles with the principal surface of the body, nothing more is necessary than to cover it over with the substance of which the mould is to be formed, and to take it off clean, and without bending. It may be laid horizontally, and will bear to be oiled without injury. The substances used for moulding are various, according to the nature and the situation of the sculpture; as wax, metal, plaster of Paris, &c. This last is prepared in a fine powder, mixed with water, and poured over the mould to a convenient thickness, after oiling it to prevent the plaster from sticking. A composition of bees' wax, resin, and pitch, makes a

very desirable mould, if many casts are to be taken. If the situation of the sculpture be perpendicular, clay, or some similar substance, must be used. The best kind of clay is that with which sculptors make their models; it is worked to a due consistence, and having been spread out to a size sufficient to cover all the surface, it is sprinkled over with whiting, to prevent it from adhering to the original. Bees' wax and dough, or the crumb of new bread, may also be used for moulding some small subjects, as impressions of seals and bijoux. When there are under-cuttings in the bas relief, they must be first filled up before it can be moulded, otherwise the mould could not be got off. When the casts are taken afterwards, the places must be worked out with a proper tool. When the model or original subject is of a round form, or projects so much that it cannot be moulded in this manner, the mould must be divided into several parts; and it is frequently necessary to cast each of them separately, and afterwards to join them together. In this case the plaster must be tempered with water to such a consistence that it may be worked like soft paste, and laid on with some convenient instrument, compressing it till it adapt itself to all parts of the surface. When the model is thus covered to a convenient thickness, the whole is left at rest till it becomes sufficiently firm to bear dividing, without falling to pieces by any slight violence; it must then be separated into pieces to be taken from the model, which is done by cutting it with a thin bladed knife. Being now divided, it must be cautiously taken off and kept till dry; but before the separation of the parts is made, they are notched across the joints at proper distances, that they may with certainty be put together again. The art of properly dividing the moulds to make them separate from the model, requires dexterity and skill. Where the subject is of a round or spheroidal form, it is best to separate the mould into three parts, which will then easily come off from the model; and the same will hold good of a cylinder, or any regular curved figure. The mould being thus formed and dry, and the parts put together, it must be first oiled and placed in such a position that the hollow may be upwards. It is then filled with plaster mixed with water, and repaired where necessary. This finishes the operation. In larger masses, where there would otherwise be a great thickness of the plaster, a core may be put within the mould, as was observed in regard to the casting of statues, to produce a hollow in the cast: this saves expense of plaster, and renders the cast lighter. In the same manner, figures, busts, &c., may be cast of lead, or any other metal, in the moulds of plaster or clay; the moulds must be perfectly dry, for should there be any moisture, the sudden heat of the metal will convert it into vapour, and produce by its expansion an explosion that would blow the melted metal about to the great danger of the artist.

To take a Cast in Metal from any small Animal, Insect, or Vegetable. Prepare a box sufficiently large to hold the animal, in which it must be suspended by a string; the legs, wings, &c. of the animal, or the tendrils, leaves, &c. of the vegetable, must be separated and adjusted in their right position by a pair of pincers. A due quantity of plaster of Paris, mixed with talc, must be tempered to a proper consistence with water, and the sides of the box oiled. Also a straight piece of stick must be put to the principal part of the body, and pieces of wire to the extremities of the other parts, that they may form, when drawn out after the matter of the mould is set and firm, proper channels for pouring in the metal, and vents for the air, which, otherwise, by the rarefaction it would undergo, from the heat of the metal, would blow it out, or burst the mould. In a short time the plaster will set and become hard; the stick and wires may now be drawn out, and the frame in which the mould was cast taken away; the mould must then be put, first into a moderate heat, and afterwards, when it is as dry as it can be rendered by that degree, removed into a greater, which may be gradually increased until the whole be red hot. The animal or vegetable inclosed in the mould will then be burnt to a coal, and may be totally calcined to ashes by blowing for some time into the charcoal and passages made for pouring in the metal and giving vent to the air. This operation, at the same time that it destroys the remainder of the animal or vegetable matter, will force out the ashes. The mould is then allowed to cool gently; the

destruction of the substance that had been included in it has now produced a corresponding hollow; but it may, nevertheless, be proper to shake the mould, and blow with bellows into each of the air vents, to free it wholly from any remaining ashes: when there may be an opportunity of filling the hollow with quicksilver, it will be found an effectual method of cleaning the cavity, as all the dust and ashes must rise to the surface of the quicksilver, and be poured out with it. The mould being thus prepared, must be heated very hot when used, if the cast is to be made of copper or brass, but a less degree of heat will serve for lead and tin. The metal being poured into the mould, it must be gently struck, and then suffered to rest till it be cold; it is then carefully taken from the cast, but without force: such parts of the matter as appear to adhere more strongly, are to be softened by soaking in water until they be loosened, that none of the more delicate parts of the cast may be broken off or bent. When talc cannot be obtained, plaster alone may be used; it is apt, however, to be calcined by the heat used in burning the animal or vegetable from which the cast is taken, and to become of too incoherent and fusible a texture. Stourbridge clay, washed perfectly fine, and mixed with an equal part of fine sand, may be employed. Pounded pumice-stone and plaster of Paris, in equal quantities, mixed with washed clay in the same proportion, make excellent moulds.

To take a Cast in Plaster from a Person's Face. The person from whom the cast is to be taken should lay down on his back, with his hair tied back, so that none may cover his face. Into each nostril a conical piece of stiff paper, open at each end, is placed to allow of breathing. The face is then to be lightly oiled over with salad oil, to prevent the plaster from sticking to the skin. Fresh burnt plaster is mixed with water to a proper consistence, and poured in spoonsful all over the face (taking care that the eyes be shut), till it is entirely covered to the thickness of a quarter of an inch. This substance will grow sensibly hot, but this inconvenience is of short duration as, in a few minutes, the plaster will set hard, and may be taken off in a complete mask, which will form a mould, in which a head of clay may be moulded, wherein the eyes may be represented as open, and such other additions or corrections made as may be found necessary. Then this second face being anointed with oil, a second mould of plaster is made upon it, consisting of two parts, jointed lengthwise along the ridge of the noise, and in this a cast in plaster is taken, which is an exact likeness of the original.

To take Casts from Medals, a mould must first be made of plaster of Paris, or of melted sulphur. After having oiled the surface of the medal with a little cotton, or a camel's hair pencil dipped in oil of olives, a hoop of paper must be put round the medal, standing up above the surface, of the thickness you wish the mould to be. Take now some plaster of Paris, mix it with water to the consistence of cream, and with a brush rub it over the surface of the medal, to prevent air-holes from appearing; then immediately afterwards make it to a sufficient thickness by pouring in more plaster. Let it stand half an hour, when it will have grown so hard that you may take it off; then pare it smooth on the back and round the edges, neatly: in cold or damp weather it should be dried before a fire. When the mould is large, if you cover its face with fine plaster, a coarse sort will do for the back; but no more plaster should be mixed up at one time than can be used, as it will soon get hard, and cannot be softened without being burned over again. Sulphur must not be poured upon silver medals, as this will tarnish them. To prepare your mould for casting sulphur, put plaster of Paris in it; take half a pint of boiled linseed oil, and one ounce of oil of turpentine, and mix them together in a bottle, dip the surface of the mould into this mixture, take the mould out again, and when it has absorbed the oil, dip it again; repeat this till the oil will no longer be absorbed. Then wipe off the oil with cotton wool, and set the mould in a dry place for a day or two, when it will be a hard surface. To cast plaster of Paris in this mould, proceed with it in the same manner as above directed for obtaining the mould itself, first oiling the mould with olive oil. When casts are wanted in sulphur, the material must be melted in an iron ladle.

To take Casts with Isinglass. Dissolve isinglass with water over the fire. With a hair pencil lay the solution carefully over the surface of the medal, and let it dry. When hard, raise the isinglass with the point of a knife, and it will fly off with a spring, leaving a sharp impression of the medal. The isinglass may be coloured with any of the water colours while in solution, or you may breathe on the concave side, and lay gold leaf upon it, which, by shining through, will give it the appearance of a gold medal. A little carmine mixed with the isinglass gives the appearance of copper, particularly if gold leaf be placed inside.

CASTORS. Small wheels fixed to heavy household furniture, as tables, sofas, &c. to admit of moving them with facility. The annexed engraving represents an improvement upon the common construction, by the introduction of small antifriction rollers, by which means the strain and pressure upon the central pin is removed, and the small wheel readily assumes the proper direction. It is the invention of Mr. Harcourt, of Birmingham. *Fig.* 1 is a side view of the castor, the upper or socket part only being in section; *a a* is a guide plate fixed round the central pin so as to revolve with it: this plate has circular holes made through it, in each of which is a little spherical ball, which rolls as it is carried round with the plate. *Fig.* 2 gives the plan of the guide plate *a*, which has three or more apertures for the antifriction rollers, and these rollers may be either spherical or cylindrical; for which reason two of them are shown in this diagram as spherical, and one as cylindrical.

Fig. 1.

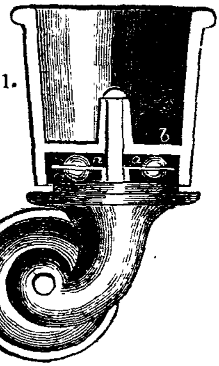
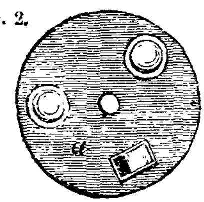


Fig. 2.



CATARACT, in hydrography, is occasioned by a precipice in the channel of a river, caused by rocks or other obstacles stopping the course of the stream, from whence the water falls with great noise and rapidity. Such are the cataracts of the Nile, the Danube, the Rhine, &c. In that of Niagara, the perpendicular fall of the water is 137 feet, and in that of Pistell Rhaiadr, in North Wales, the fall of water is nearly 240 feet from the mountain to the lower pool.

CATECHU, or JAPAN EARTH. An extract prepared in India from the juice of the *mimosa catechu.* In its present state it is a dry pulverable substance, outwardly of a reddish colour, and internally of a shining dark brown, tinged with a reddish hue. It contains a greater portion of tannin than any other vegetable matter, and what is very remarkable, no gallic acid.

CATENARIA, or CATENARY. In the higher geometry, the curve line formed by a line or cord hanging freely between two points of suspension, whether those points be horizontal or not. The properties of this curve have been practically applied in the construction of suspension bridges, for a description of which see BRIDGES.

CATOPTRICS, is that part of science which treats of the laws and properties of light reflected from mirrors or specula. The whole doctrine of catoptrics depends on this simple principle, namely, that the angle of incidence is equal to the angle of reflection.

CATOPTRIC CISTULA. An arrangement of mirrors in a kind of box, by which objects are represented as multiplied, magnified, or deformed. A variety of pleasing phenomena are exhibited by machines of this kind.

CATOPTRIC, or REFLECTING DIAL, is a kind of dial which shows the hours by means of a piece of looking-glass plate, adjusted to reflect the solar rays upwards to the ceiling of a room, on which the hour lines are delineated.

CATOPTRIC TELESCOPE. Instead of lenses, this telescope is furnished chiefly with mirrors, and exhibits remote objects by reflection instead of refraction.

CAT'S EYE. A mineral of a beautiful appearance, brought from Ceylon. Its colours are grey, green, brown, and red, of various shades; and from a peculiar play of light proceeding from interposed white fibres, it has derived its name. It is valued for setting as a precious stone.

CAULKING is a term applied in ship-building to the driving of a quantity of oakum, saturated with tar, into the seams between the planks of ships, which is effected by a blunt chisel and a mallet. After the oakum has been driven very hard into the seams, it is covered with hot melted pitch or resin, to preserve it against the effects of the water. The term caulking is, however, now extensively applied to other operations of a similar nature; thus engineers in closing up the junctures between the flanges of pipes or plates of iron, caulk them with iron cement.

CAUSTIC. A term in chemistry, applied to alkalies when deprived of carbonic acid by means of quick lime.

Caustic (*Lunar*). A preparation of silver dissolved in nitrous acid, and afterwards fused and formed into small cylindrical pieces in a mould.

CAWK. A term given by miners to the opaque sulphate of barytes.

CEMENTATION. A chemical process, which consists in surrounding a body in the solid state with the powder of some other bodies, and exposing the whole for a time to a degree of heat not sufficient to fuse the contents. Thus iron is converted into steel by powdered charcoal; green bottle glass into porcelain, by sand, &c.

CEMENTS, in general, are substances employed to unite bodies in close adhesion, for which purpose they are applied in a semi-fluid or pasty state, so as to be brought into intimate contact with the opposite surfaces, and becoming solid as the moisture exhales, the whole form, as it were, one mass. Cements are variously composed, according to the nature of the surfaces to which they are applied, and their exposure to heat or moisture. We shall here annex the processes of preparing and mode of employing those which are in the most esteem.

Cement for Steam. The following methods are adopted by machinists to join the flanges of iron cylinders, and other parts of hydraulic and steam engines. Boiled linseed oil, litharge, red and white lead, mixed together to a proper consistence, applied on each side of a piece of flannel, previously shaped to fit the joint, and then interposed between the pieces before they are brought home, as the workmen term it, to their place, by the screws or other fastenings employed, make a close and durable joint. The quantities of the ingredients may be varied without inconvenience, taking care not to make the mass too thin. It is difficult in many cases instantly to make a good fitting of large pieces of iron work; this renders it necessary sometimes to join and separate the pieces repeatedly before a proper adjustment is obtained. When this is required, the white lead ought to predominate in the mixture, as it dries much slower than the red. A workman knowing this fact, can be at little loss in exercising his own discretion in regulating the quantities. It is safest to err on the side of the white lead, as the durability of the cement is not thereby affected; a longer time only is required for it to dry and harden. When the fittings will not easily admit of so thick a substance as flannel being interposed, linen, paste-board, or even paper, may be substituted. Stones that are broken, however large, may be joined together very well with this cement, and cisterns put together with it will never leak. In this case, the stones need not be entirely bedded in it; an inch, or even less, of the edges that are to be next the water, need only be so treated; the rest of the joint may be filled up with good lime.

Iron Cement. Take two ounces of muriate of ammonia, one of flour of sulphur, and sixteen of cast-iron filings or borings. Mix them well in a mortar, and keep the powder dry. When the cement is wanted for use, take one part of this mixture, twenty parts of clear iron borings or filings, grind them together in a mortar, mix them with water to a proper consistence, and apply them between the joints. This cement is in extensive use by iron founders, and is found to be very excellent, as in time it unites with the iron as one mass.

Cement for Iron Boilers. Six parts of clay, one of iron filings, and linseed

oil sufficient to form a thick paste, make a good cement for stopping cracks in iron boilers.

Cement for Copper Boilers. Powdered quick lime mixed with bullock's blood is often used by coppersmiths, to lay over the rivets and edges of the sheets of copper in large boilers, as a security to the junctures, and also to prevent cocks from leaking.

Cements for Jewellers, Lapidaries, &c. It sometimes happens, that jewellers, in setting precious stones, by accident break off pieces; in this case they join them, so that it cannot easily be seen, with gum mastic, the stone being previously made hot enough to melt it. By the same medium cameos of white enamel, or coloured glass, are often joined to a real stone as a ground, to produce the appearance of an onyx. Mastic is likewise used to cement false backs or doublets to stones, to alter their hue. The jewellers in Turkey, who are generally Armenians, ornament watch-cases and other trinkets with gems, by glueing them on. The stone is set in silver or gold, and the back of the setting made flat to correspond with the part to which it is to be applied. It is then fixed on with the following cement: isinglass, soaked in water till it swells up and becomes soft, is dissolved in French brandy or in rum, so as to form a strong glue. Two small bits of gum galbanum, or gum ammonicum, are dissolved in two ounces of this by trituration, and five or six bits of mastic, as big as peas, being dissolved in as much alcohol as will render them fluid, are to be mixed with this by means of a gentle heat. This cement is to be kept in a phial closely stopped; and when used, it is to be liquefied by immersing the phial in hot water. This cement will resist moisture. Temporary cements are wanted in cutting, grinding, or polishing optical glasses, stones, and various small articles of jewellery, which it is necessary to fix on blocks, or handles, for the purpose. Four ounces of resin, a quarter of an ounce of wax, and four ounces of whiting, made previously red hot, form a good cement of this kind, as any of the above articles may be fastened to it by heating them, and removed at pleasure in the same manner, though they adhere very firmly to it when cold. Pitch, resin, and a small quantity of tallow, thickened with brick dust, is much used at Birmingham for these purposes. Four parts of resin, one of bees'-wax, and one of brick-dust, likewise make a good cement. This answers extremely well for fixing knives and forks in their hafts; but the manufacturers of cheap articles of this kind too commonly use resin and brick-dust alone. On some occasions, in which a very tough cement is requisite, that will not crack though exposed to repeated blows, as in fastening to a block metallic articles that are to be cut with a hammer and punch, workmen usually mix some tow with the cement, the fibres of which hold its parts together. Seven or eight parts of resin, and one of wax, melted together, and mixed with a small quantity of plaster of Paris, is a very good cement to unite pieces of Derbyshire spar, or other stone. The stone should be made hot enough to melt the cement, and the pieces should be pressed together as closely as possible, so as to leave as little as may be of the cement between them. This is a general rule in cementing, as the thinner the stratum of cement interposed, the firmer it will hold.

Cement for Electrical Apparatus. One pound of bees'-wax added to five pounds of resin, one pound of red ochre, and two table-spoonfuls of plaster of Paris, all mixed together, make an excellent composition; but a cheaper one, for cementing voltaic plates into wooden troughs, is made with six pounds of resin, one pound of red ochre, half a pound of plaster of Paris, and a quarter of a pint of linseed oil. The ochre and plaster of Paris should be well dried, and added to the other ingredients in a melted state.

Universal Cement, particularly adapted for joining glass, porcelain, and metallic surfaces, is thus prepared. To an ounce of mastic add as much highly rectified spirits of wine as will dissolve it. Soak an ounce of isinglass in water until quite soft, then dissolve it in pure rum or brandy, until it forms a strong glue, to which add about a quarter of an ounce of gum ammoniac, well rubbed and mixed. Put the two mixtures together in an earthen vessel, over a gentle heat; when well united, the mixture may be put into a phial, and kept well stopped. When wanted for use, the bottle must be set in warm

water, the china or glass articles must be also warmed, and the cement applied. It will be proper that the broken surfaces, when carefully fitted, shall be kept in close contact for twelve hours at least, until the cement is fully set; after which, the fracture will be found as secure as any part of the vessel, and scarcely perceptible.

Cement for Chemical Glasses. Mix equal quantities of wheat flour, finely powdered Venice glass, pulverized chalk, with half the quantity of fine brick-dust, and a little scraped lint, into some whites of eggs. This mixture must then be spread upon a linen cloth, and applied to the crack of the glasses; it should be dried before they are put to the fire.

Cement for Stone Paper or Artificial Slates. Linseed oil rendered drying, intimately mixed with white-lead and chalk: this should be used in a nearly fluid state, as by doing so it will insinuate itself amongst the joints and interstices, and cover the heads of the nails perfectly.

Water Cements, or Roman Cements, harden under water, and consolidate almost immediately on being mixed. The ancient Romans, in making their water cements, employed a peculiar earth obtained at the town of Puteoli. This they called *Pulvis Puteolanis:* it is the same that is now called Puzzolana There is a substance called *tarras, terras* or *trass,* mostly employed by the Dutch in their great aquatic structures. It is very durable in water, but inferior to the other kinds in the air. In an analysis of Parker's Roman cement, by Monsieur Berthier, he finds that its constituents differ so little from the constituents of chalk and common clay, that he proposes the manufacturing of a similar cement by the mere mixture of them in certain proportions. One part of clay, and two and a half parts of chalk, sets almost instantly, and may therefore be regarded as Roman cement. If clay and oxide of iron be mixed with oil, according to Mr. Gad, of Stockholm, they will form a cement that will harden under water. It has been discovered that manganese is a valuable ingredient in water cements: four parts of grey clay are mixed with six of the black oxide of manganese, and ninety of good limestone, reduced to fine powder; then the whole is calcined to expel the carbonic acid. When this mixture has been well calcined and cooled, it is to be worked into the consistence of a soft paste, with sixty parts of washed sand. If a lump of this cement be thrown into water, it will harden directly.

Turners' Cement. Melt together resin one pound, pitch four ounces; and while boiling-hot, add brick dust, until, by dropping a little upon a stone, you perceive it hard enough; then pour it into water, and immediately make it up in rolls, and it will be fit for use. A finer cement is made of pitch two ounces, resin one ounce, and red ochre finely powdered. A small quantity of tallow is used sometimes, according to the heat of the weather, more being necessary in winter than summer. Either of these cements are of great use to turners. By applying it to the side of a chuck, and making it warm before the fire, you may fasten any thin piece of wood, which will adhere while it is turned; when it is wanted off again, it need only be struck on the top with a tool, and it will immediately fall off.

Rice Cement. This useful and elegant cement, which is beautifully white, and dries almost transparent, is made by mixing rice flour intimately with cold water, and then gently boiling it. Papers pasted together with this cement will sooner separate in their own substance than at the joining. It is, therefore, an excellent cement in the preparation of curious paper articles, as tea-trays, ladies' dressing and work boxes, and other articles which require layers of paper to be cemented together. In every respect it is preferable to common paste made with wheat flour. It answers well for pasting into books the copies of writing taken off by copying machines on unsized silver paper. With this composition, made with a small quantity of water, that it may have a consistence similar to plastic clay, models, busts, statues, basso-relievos, and the like, may be formed. When dry the articles made of it are susceptible of a high polish; they are also very durable. The Japanese make quadrille fish of this substance, which so nearly resemble those made of mother-of-pearl, that the officers of our East Indiamen are often imposed upon.

Parolic Cement. To prepare this cement, take the unsalted curd of skimmed milk, after pressing the whey out of it, and break it into lumps; distribute these lumps upon linen sheets laid upon the floor of an airy room to dry; and frequently, from time to time, as the curd acquires greater consistency, stir and break it into smaller masses, either with the hands, or with the assistance of a flat board, and a bar or rubber of wood, until at length it becomes dry enough to grind in a steel coffee-mill to a powder about as fine as the best gunpowder, when it must be gently dried over a stove, and kept dry for use. 100 lbs. of curd from the cheese-press will only afford about 30 lbs. of the dry curd. To 90 parts of this dried curd, 10 parts of caustic quick lime, made of blue marble, finely rubbed to powder and searced, and 1 part of camphor, must be added, and well mixed, by rubbing the whole together with a pallet-knife upon a stone slab; and the whole must be then inclosed in bottles, holding about an ounce each, and well corked immediately afterwards, in order to prevent the access of air to the composition. In this state the cement will remain good a long time; and when wanted for use, a little of it must be poured out upon any flat earthen plate, &c., and, by the aid of a pallet or case-knife, be instantly mixed with a proper quantity of water, to render it of a fit consistency for the purpose to which it is to be applied. The bottle must be again carefully closed, after taking out the quantity of cement required, as, otherwise, the lime would lose its causticity, upon which its solvent action, or the caseous part of the cement, entirely depends.

The manufacture of that important and valuable cement, glue, is described in its initial order in this work.

CENTRAL FORCES. The two antagonist forces by which bodies are caused to revolve round a central point. As all forces act in right lines, the tendency of any body moving in a circle is to fly off in a right line forming a tangent to the circle, and this tendency is called the centrifugal force; and the force by which it is restrained from so flying off, and which maintains it in its curvilinear path, is termed the centripetal force; and these two forces are necessarily equal to each other. Dr. Brewster has summed up the whole doctrine of the central forces in the following propositions. 1. The centrifugal forces of two unequal bodies moving with the same velocity, and at the same distance from the centre of motion, are to one another as the respective quantities of matter in the two bodies. 2. The centrifugal forces of two equal bodies which perform their revolutions round the central body in the same time, but at different distances from it, are to one another as their respective distances from the central body. 3. The centrifugal forces of two bodies which perform their revolutions in the same time, and whose quantities of matter are inversely as their distances from the centre, are equal to each other. 4. The centrifugal force of two equal bodies moving at the same distance from the central body, but with different velocities, are to one another as the squares of the velocities. 5. The centrifugal forces of two unequal bodies moving at equal distances from the centre with different velocities, are to one another in the compound ratio of their quantities of matter and the squares of their velocities. 6. The centrifugal forces of two equal bodies moving with equal velocities at different distances from the centre, are inversely as their distances from the centre. 7. The centrifugal forces of two unequal bodies moving with equal velocities at different distances from the centre, are to one another as their quantities of matter multiplied by their respective distances from the centre. 8. The centrifugal forces of two unequal bodies moving with unequal velocities at different distances from the centre, are in the compound ratio of their quantities of matter, the squares of their velocities, and their distances from the centre.

To find the centrifugal force of any body:—Divide the velocity in feet per second by 4.01, and the square of the quotient by the diameter of the circle; the quotient is the centrifugal force when the weight of the body is 1. Hence the quotient, multiplied by the weight of the body, is the centrifugal force required.—*Ex.* Required the centrifugal force of the rim of a fly-wheel 20 feet in diameter, moving with a velocity of $32\frac{1}{6}$ feet per second:

$$32\tfrac{1}{6} \div 4.01 = 8.02 \text{ and } 8.02^2 \div 20 = 3.216 \text{ times the weight of the rim.}$$

Rule 2.—Multiply the square of the number of revolutions per minute, by the diameter of the circle in feet, and divide the product by the constant number 5870, and the quotient is the centrifugal force when the weight of the body is 1; and this quotient, multiplied by the weight of the body, is its centrifugal force. *Ex.* Required the centrifugal force of a stone weighing 2 lbs., revolving in a circle of 4 feet diameter, at the rate of 120 revolutions per minute:

$$120^2 \times 4 = 57600 \text{ and } \frac{57600}{5870} = 9.81$$

hence $9.81 \times 2 = 19.62$ centrifugal force.

CENTRE OF GRAVITY. A point in any body about which all the parts are in equilibrio; so that if the body be suspended or supported by this point, it will remain in any position in which it may be placed. The centre of gravity of any plane may be found mechanically as follows: suspend the plane by a point in or near its perimeter, and when it is at rest, draw across it a vertical line, passing through the point; suspend it in like manner by another point, and draw a vertical line as before; the intersection of these lines is the centre of gravity.

CENTRE OF GYRATION is that point in a body revolving about an axis, into which, if the whole quantity of matter were collected, the same moving force would generate the same angular velocity.—To find the centre of gyration: multiply the weight of the several parts of the body by the squares of their distances from the centre of motion, and divide the sum of the products by the weight of the whole mass, and the square root of the quotient will be the distance of the centre of gyration from the centre of motion.

CENTRE OF OSCILLATION is that point in a body suspended from a point and made to vibrate, in which all its force is collected, and to which point, if an obstacle were applied, all its motion would cease. To find the centre of oscillation in a compound pendulum:—Multiply all the parts or bodies of which the pendulum is composed, each by the square of its distance from the point of suspension, and divide the sum of the products by the product of the whole weight of the pendulum, multiplied by the distance of the centre of gravity from the point of suspension.

CENTRE OF PERCUSSION. That point in a body revolving about a fixed axis into which the whole force or motion is collected; it is, therefore, that point of a revolving body which would strike an obstacle with the greatest effect, and from this property it has received the name of the centre of percussion. The centres of percussion and of oscillation are generally treated separately, but the two centres are in the same point, and therefore their properties are the same. As in bodies at rest the whole weight may be considered as collected in the centre of gravity, so in bodies in motion, the whole force may be considered as concentrated in the centre of percussion; therefore, the weight of the rod multiplied by the distance of the centre of gravity from the point of suspension, will be equal to the force of the rod divided by the distance of the centre of percussion from the same point. For example: suppose a rod, 12 feet long, and weighing 2 lbs. per foot, with two balls of 3 lbs. each, one fixed 6 feet from the point of suspension, and the other at the end of the rod; what is the distance between the points of suspension and of percussion?

$12 \times 2 \times 6$	$= 144$	momentum of rod.
3×6	$= 18$	ditto of first ball.
3×12	$= 36$	ditto of second ball.
	198	momentum of balls and rod;

and the weight of the rod multiplied by the square of its length, and divided by 3=to the force of the rod; and the weight of the bal' multiplied by the square of their distance from the point of suspension=to t . force of the ball. Therefore—

$$\frac{24 \times 144}{3} = 1152 \text{ the force of the rod}$$

$$3 \times 36 = 108 \text{ ditto of the first ball}$$

$$3 \times 144 = 432 \text{ ditto of the second ball}$$

$$1692 = \text{force of balls and rod,}$$

and $1692 \div 198 = 8.545$ feet from the point of suspension. In a slender rod, of small breadth as compared with its length, the distance of the centre of percussion is nearly two-thirds of its length from the point of suspension. In an isoceles triangle, suspended by its apex, and vibrating in a plane perpendicular to itself, the distance of the centre of percussion is three-fourths of its altitude; and the same thing holds with regard to fly-wheels, or wheels in general.

CENTRE, or Centering. The framing of timber by which an arch or vault is supported during its erection. See Bridge.

CENTRIFUGAL MACHINE. A machine invented by Mr. Erskine for raising water by means of a centrifugal force combined with the pressure of the atmosphere. This machine consists of a vertical tube resting upon a pivot, and having at top two horizontal hollow arms, near the extremity of each of which, but on opposite sides, is a valve opening outwards; whilst near the bottom of the vertical tube, and below the surface of the water to be raised, is a valve opening inwards. On the upper part of the arms are two holes, with screw-caps, and through these holes water is poured previous to setting the machine in motion; by which means the air is forced out of the machine, and the water supported in the tube by the foot-valve at the bottom. The holes in the arms being secured by their screw-caps, and a rapid rotatory motion being communicated to the tube, the water in the arms acquires a centrifugal force, opens the valves near the extremity of the arms, and flies out with a velocity nearly equal to that of the arms, discharging itself into a circular trough. Although extremely ingenious and simple, this machine is not equal in effect to a well-made pump; and as the fluid is forced up the vertical tube into the arms by the pressure of the atmosphere, it is incapable of raising water to a height exceeding 33 feet.

CERATE. A compound of hog's lard or oil with bees' wax, employed in surgery.

CERIN. That part of common wax which is dissolved by alcohol.

CERIUM. A newly discovered metal found in the mineral cerite. It has not yet been obtained in a useful metallic form.

CERUSE, or White Lead, is commonly made by coiling up very thin cast sheets of lead into rolls, so as to leave a small space between each fold. The rolls thus formed are lightly jammed into the mouths of a number of earthenware pots, which are about half filled with vinegar. These pots are placed in a situation where a very gentle heat will cause a slow evaporation of the vinegar, in order that it may gradually operate upon the lead. A layer of several hundreds of them are usually deposited either in a bed of tanner's spent bark, or dung, contained in a wooden frame. Boards are then laid over the tops of these pots, and on this temporary floor, which is supported by boards placed edgeways, is laid another layer of pots similarly furnished. Seven such layers of pots are placed in succession over each other, to form a stack. When the vinegar is found to be completely evaporated in these stacks, which generally occupies three months, they are taken down; the corroded lead is taken out of the mouths of the pots, but as the adhesion to the latter is very strong, many of them are broken in getting out the lead, and the poisonous dust which the workmen inspire by this operation, lamentably impairs their health, and they are often in consequence afflicted with the disease called the Devonshire, or painter's colic. To avoid this serious evil, and economize the process, a different and more mechanical arrangement has been made. The base of the stack is made of a layer of pots *filled* with vinegar only; over these is supported, by planks on edge, a floor of boards, pierced with numerous holes to allow the passage of the acid vapour; on these perforated boards are then

laid the rolls of lead, then another perforated floor, and another layer of rolls, until the stack is completed. By this arrangement it is said that the manufacturer obtains one-third more white lead, saves his pots from breakage, and avoids the dust so pernicious to the workmen by first sprinkling the rolls with water. Upon uncoiling the plates, the white substance that falls off is the purest white lead, and is disposed of for the finest work under the name of *flake white;* a portion of the latter is ground up with water, formed into small lumps, and sold under the name of *ceruse*. But all the white lead that is subsequently taken off the plates is ground up either with water, and sold in large lumps, or it is ground with oil, and is usually more or less adulterated with whiting, to suit the various prices at which it is required in the market. As the processes employed in France and Germany for the manufacture of ceruse appear to be well worthy of attention, we shall here annex some account of them. In France the first part of the process consists in dissolving 174 lbs. of finely-ground litharge in 65 lbs. of pyroligneous acid, of such strength that 22½ grains of this acid will saturate 25 grains of sub-carbonate of soda; fifteen to twenty times as much water is usually added. The whole is left for a short time, and the clear portion being decanted off, some fresh acid and water is poured on the sediment, to take up any oxide that might have escaped the action of the first parcel. The decanted solution is run into large shallow covered cisterns, into which carbonic acid gas is passed through numerous pipes. When the settling appears to be completed, the whole is passed into a deep cistern, and left there for some hours, when the liquid part is to be poured off, in order to be combined with more litharge, some fresh acid being also added. After the desired tint has been given to the lead, it is well drained, put into glazed pots of the proper shape to imitate the Dutch white lead leaves, then dried in stoves, and lastly, packed in blue paper to heighten the effect of its beautiful colour.

In Germany the first part of the process consists in casting the pure lead of Corinthia into very thin sheets, which is effected by pouring the liquid metal upon inclined sheets of iron. The sheets of lead are trimmed to a proper size, and suspended over an acid liquor contained in boxes, which are usually about 5 feet long, 1 foot broad, and 10 inches deep; and they are pitched internally on the bottom, and rising therefrom about 2 inches at the sides. Sticks are placed across the boxes, and the sheets of lead are doubled so as to be suspended in the middle by them, but so as not to touch each other, nor the acid liquor deposited underneath them. The liquor in some manufactories is made of equal parts of vinegar (obtained from crab apples) and wine lees, and about two gallons of this mixture is apportioned to each box. Some manufacturers use 20 pints of vinegar, 8 pints of wine lees, and 1 lb. of pearl ash. The usual mode is to dispose the boxes in a large room heated up to 87° Fahrenheit; a greater heat would evaporate the acid too fast. In about a fortnight the corrosion is finished, rendering the sheets about a quarter of an inch thick, and partially covered with crystals of sugar of lead. Those crystals that are easily detached are carefully washed; during this operation a white scum appears, which is taken off, and a little pearl ash being added to it, it is changed into ceruse of a beautiful whiteness, and is sold for the choicest purposes; the remainder is mixed in different proportions with the pure sulphate of barytes, brought from the Tyrol.

CETINE. The name given by Chevreul to spermaceti, which is extensively adopted. See Fat.

CHAFF-CUTTING MACHINE, as its name denotes, is a machine for cutting chaff for cattle, which being an object of some consequence on large farms, and in establishments employing many horses, a variety of machines have been invented for the purpose of performing the operation with facility and dispatch. For a highly-improved machine of this description, see the article Straw.

CHAIN. A series of links of metal engaged one within the other; also, in surveying, a measure of length, made of a certain number of links of iron wire. That which is most commonly used for this purpose, called Gunter's chain, is composed of 100 links=4 poles, or 66 feet; and 1 square chain= 10,000 links=16 poles; 10 square chains=100,000 links=160 poles=1 acre

CHAIN PUMP. See Pumps.

CHALDRON. An English measure for coals, containing 12 sacks, or 36 bushels. The bushel measures are always heaped up, and on shipboard, 21 chaldrons are allowed to the score.

CHALK. A species of carbonate of lime.

CHALYBEATE. Mineral water impregnated with iron is so called.

CHARCOAL. The fixed residue of vegetables exposed to a strong heat whilst protected from the access of the atmospheric air. In countries where wood abounds, charcoal is prepared by forming it into a conical stack, covered with clay and turf to the depth of several inches, leaving an aperture at the top for the escape of the smoke, and several small apertures at bottom for the admission of air at first lighting of the pile, but which are carefully closed as soon as the ignition is supposed complete. Charcoal is also made on a great scale by charring wood in iron cylinders, as described under the head of Acetic Acid. Charcoal has been prepared lately in France from turf or peat, and is said to be superior to that prepared from wood. In a goldsmith's furnace it fused 11 ounces of gold in 8 minutes; whilst wood charcoal required 16 minutes to produce the same effect. The malleability of the gold, too, was preserved in the former instance, but not in the latter. From the scarcity of wood in this country, pitcoal charred is much used instead of charcoal, and is known by the name of coke.

CHARGE, in gunnery, the quantity of powder and shot which is necessary to load a piece of ordnance, in order that when fired it may produce the intended effect. For proving guns the weight of the powder is always equal to that of the ball; but the charge of powder generally esteemed sufficient for service is one-half or one-third the weight of the ball, or even less. Dr. Hutton found, from many experiments, that the length of the charge producing the greatest velocity, in guns of various lengths of bore, from 15 to 40 calibres, is as follows:—

Length of bore.		Length of charge.	
15	calibres.	$\frac{3}{10}$	the length of the bore.
20		$\frac{3}{12}$	
30		$\frac{3}{16}$	
40		$\frac{3}{20}$	

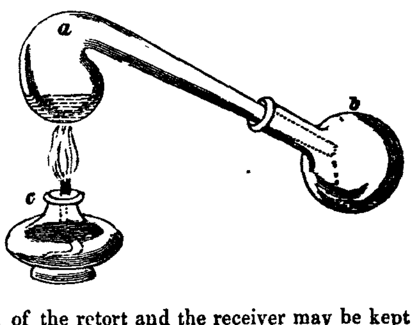
CHAYA ROOT. The root of *Oldenlandia umbellata*, which grows wild on the coast of Coromandel, and is likewise there cultivated for the use of the dyers and calico printers. It is used for the same purposes as madder with us, to which it is said to be far superior, giving the red so much admired in the Madras cottons.

CHEESE. An article of food obtained by mixing an acid with milk, which causes it to coagulate and form a curd; the curd is then subjected to the action of a powerful press to separate it from the whey, after which it is set upon racks to dry. The quantity of curd is less when a mineral acid, than when a vegetable acid is used; but the substance which answers best for this purpose, and indeed which is almost the only one employed in England, is rennet, which is made by macerating in water the last stomach of a calf, salted and dried for this purpose. Cheese is made in several parts of England, but that made in Chester is generally esteemed superior to all others. An excellent account of the mode of making it will be found in Vol. XI. of *Tillock's Magazine*, taken from the agricultural report of the county. "If the milk," says the reporter, "be set together very warm, the curd, as before observed, will be firm; in this case, the usual mode is to take a common case knife, and make incisions across it to the full depth of the blade of the knife, at the distance of about 1 inch, and again crossways in the same manner, the incisions intersecting at right angles. The whey rising through these incisions is of a fine pale green colour. The cheese-maker and two assistants proceed then to break the curd; this is performed by their repeatedly putting their hands down into the tub, the cheese-

maker with the skimming dish in one hand, breaking every part of it as they catch it, raising the curd from the bottom, and still breaking it. This part of the business is continued till the whole is broken uniformly small; it generally takes up about 40 minutes, and the curd is then left covered over with a cloth to subside." The cheese is subsequently broken by hand, mixed with salt, and put into a vat, in which it is pressed with loaded boards, and then is turned over upon a cloth into another vat, with a tin hoop or binder over the upper part of the cheese, and within the sides of the vat, and then pressed for about 8 hours, being twice turned in the vat during that time. It is then set to dry, being turned twice a day for the first week, and then cleared and turned once daily for three weeks longer, after which it is removed to the common cheese-room, where it is laid upon straw upon a boarded floor until it acquires the proper hardness.

CHEMISTRY is the science which teaches the composition, properties, and uses, of all material bodies. It is the business of Mineralogy to investigate the properties and uses of inorganic substances as they *naturally* occur, but it is the office of chemistry to reduce, not only them, but all organic bodies, to their primitive elements, and having discovered the component parts and their proportions, to aim at their reproduction, when such reproduction would be beneficial to man. Under this head we shall give but a short sketch of this extensive science, as it will be necessary to explain the nature and mode of operation of those potent agents, Light, Heat, and Electricity; and as each substance which is the object of chemical research will be described under the initial letter of its name. For the history of this science we must refer our readers to *Brande's Manual*, or some other systematic work on the science, as its details would be far too multifarious to be compatible with the limits of this work. The science of chemistry will be found to depend chiefly on the operation of the different degrees of attraction which the various elementary bodies have for each other. Every mass of matter on the earth, or diffused through the universe, is found to tend towards every other mass. This tendency is expressed by the term *gravitation*, and it is found to increase in intensity as the masses are nearer in the proportion of the squares of the distances between them. If, however, we examine this power in individual masses, we shall find it act with much greater intensity, and to vary its force in different bodies; it is then called *affinity.* The former species of attraction, or that acting on masses at sensible distances, forms the particular object of study in mechanical philosophy; while the action of the particles on each other at insensible distances is the object of chemical philosophy. When this affinity acts between particles of the same kind, it is called cohesion; but when it operates between particles of a different kind, it is called chemical attraction, the attraction of composition, or sometimes simply affinity. One particle of copper is attached to another particle of copper by *cohesion;* also a particle of sulphate of copper to another particle of the same substance; but when a particle of copper unites with a particle of sulphuric or nitric acid, it is an instance of chemical affinity. The attraction of cohesion, as well as the power of repulsion, which is opposed to it, are both opposed to chemical attraction. A lump of sugar or salt is much more readily dissolved if previously broken into pieces or pulverized, than if left in the solid form which cohesion imparts to it. Chemical attraction has been distinguished into three degrees or states of energy: the result of the lowest kind is *mixture;* of the second, *solution;* and of the third and most energetic, *composition.* Chemical *mixture* takes place when the particles of two bodies are in a like state, and the power of cohesion, with regard to them, so far suspended, as to admit of that freedom of motion between themselves upon which fluidity depends; thus, two liquids or two aëriform fluids may admit of mixture, but two solids can be chemically mixed only by diminishing their cohesion by means of heat to such a degree as to bring one or both to the state of liquids. Between some fluids there appears to be no attraction, and hence they do not admit of mixture; thus, if water and oil, or water and mercury be agitated together, they will separate as soon as they are allowed to remain at rest, the denser body occupying the lower place; but sulphuric acid and water, or alcohol and water, have a

strong attraction for each other, and when mixed, do not separate by repose, although the density of the ingredients materially differs. The atmosphere in which we live and breathe is an example of the mixture of aëriform bodies: it is composed of two gases—oxygen and nitrogen, which are mingled with surprising uniformity. They may be separated from each other, and the properties of the latter exhibited, by burning a little sulphur under a bell glass over water. By this process the oxygen is removed, combining with the sulphur, and the nitrogen remains. The properties of these gases will be discussed hereafter under their respective names. Unlike liquids, all aëriform bodies have the property of mixing together. This difference is considered to arise from a modification of attraction between their constituent particles. In the case of liquids not mixing, the attraction of cohesion between similar particles is probably greater than the chemical attraction between the dissimilar particles. In gaseous bodies the attraction of cohesion does not appear to exist, and chemical mixture operates unopposed. The expansive power of heat is opposed to cohesion, and hence this attraction may be so far counteracted, that solid bodies shall assume the fluid state, and may then be mixed together; thus, melted tin may be mixed with melted lead or copper, and their particles remain combined after they have resumed the solid state. Chemical *mixture* may take place between two bodies in any proportion. Equal measures of sulphuric acid and water may be commingled, or a single drop of the former may be mixed with a pint or a gallon of the latter, and the mixture will be uniform and perfect. Chemical mixture is often attended by condensation or diminution of volume. If equal measures of sulphuric acid and water are mixed, the mixture will not fill two measures: this contraction is usually accompanied with an increase of temperature. If four parts of sulphuric acid be suddenly mixed with one of water, both at ordinary temperatures, the heat of the mixture will be higher than that of boiling water. The properties of bodies are not essentially changed by moisture; in general, however, those of the more active prevail. A few drops of sulphuric acid will communicate a sour taste to a quart of water. The separation of liquid mixtures may be effected either by the addition or subtraction of heat, arising from the unequal effect produced by this agent on different bodies. By carefully applying heat to a mixture of alcohol and water, the spirit will rise in vapour, and leave the water pure; this process is called *evaporation*. If the more evaporable fluid is condensed and received into a separate vessel, it is termed *distillation*. This process may easily be performed in a small way by using a retort and receiver. In the annexed cut *a* is the retort, containing the mixed liquid, which may be spirit and water, or a little wine or ale; *b* is the receiver, into which the neck of the retort must pass through a cork; *c* is the spirit lamp, which furnishes heat for the distillation. As soon as the heat is applied, the spirit being more easily vapourized, rises to the top of the retort, where, being condensed into the liquid state, it slowly trickles down the neck into the receiver. The neck of the retort and the receiver may be kept cool, by applying cloths, constantly moistened with cold water, to their external surface. The spirit may also be separated from the water by intense cold, which freezes the water, and leaves the spirit in its liquid state. Mixtures of gaseous fluids are not separable by heat or cold, for they all expand equally by equal additions of heat; but steam, and other vapours, may be separated from gases by reduction of temperature, which destroys the elasticity of the former, but not of the latter. The second degree of chemical attraction is *solution*, which operates between solids and liquids, or gases and liquids; the liquids, in these cases, are called solvents. Between some liquids and solids attraction



does not exist, or it is overbalanced by the cohesive power. Resin and sealing wax are insoluble in water, but readily dissolve in alcohol. Chemical attraction may be exerted in different degrees between one body and several others. There is an affinity between alcohol and water, whereby they are capable of mixing; there is also a mutual affinity between alcohol and resin, by which the former dissolves the latter; but there is no affinity between water and resin. Now, if water be added to a solution of resin in alcohol, the resin will resume the solid form; the attraction between the particles of alcohol and those of water is greater than that between the particles of resin and alcohol: the consequence is, that the alcohol quits the resin and combines with the water, and the resin falls to the bottom of the liquid. This is called *elective attraction*, because the alcohol may be considered as exercising a choice between the substances with which it is capable of combining. This resumption of the solid form by a body previously dissolved in a liquid, is termed *precipitation*. The power of solution is limited, as liquids cannot combine with more than a certain definite quantity of any solid or aëriform body. The point at which the action between the two bodies ceases is called the point of *saturation*. Up to this point the two bodies may combine in any proportions. A solvent that has been saturated with one substance, is often capable of combining at the same time with others; thus water that is saturated with saltpetre will dissolve a considerable quantity of common salt. The influence of heat upon the power of solution corresponds with the difference between cohesion and elasticity. Upon solid bodies it generally increases the power of the solvent by diminishing their cohesion. Upon aëriform bodies it diminishes the power by increasing their elasticity. Solvents may be separated from the bodies with which they are united by alterations of temperature. If a solution of alum or common salt be boiled, the liquid will be dissipated in vapour, but the solid salt will remain. If a solution of carbonic acid in water be frozen, the gas will escape and the water remain in the solid state. The result of the highest degree of chemical attraction is *composition*, which may take place between bodies under every modification of cohesive attraction. Bodies that unite in this intimate manner combine only in definite proportions, which are invariable in the same compound. Combination usually produces a total change in the sensible properties of the combining substances; and the process is generally accompanied by change of temperature, to such an extent sometimes that light and heat are emitted in abundance. If copper filings and sulphur be mixed together, and heat applied as soon as the sulphur melts, a violent action will take place, the copper will become red hot, and a black brittle body will be formed, with properties totally different from those of its two ingredients. This compound, which is the sulphuret of copper, is often found ready formed in mineral veins; but whether existing naturally, or formed by art, its composition is definite and invariable. It is found to consist of 64 parts by weight of copper, and 16 of sulphur. There is, however, another compound of copper and sulphur, in which the proportions are 64 copper to 32 of sulphur. In this it will be seen that the quantity of sulphur is exactly double of that which the first combination contains. This is a fact of common occurrence; many bodies will unite in two or three different proportions, but they are no less definite, each being a multiple, or a submultiple, of the preceding; that is, it is double, triple, or half, and so on. This is well illustrated in the compounds of mercury. If this brilliant and fluid metal be agitated for a long time in contact with the common air, it will unite with the oxygen of that mixture, and will be converted into a black, insipid, insoluble powder, which consists of 200 parts of mercury to 8 of oxygen. If instead of being agitated at common temperatures with the air it be kept nearly boiling in it, it will be converted into a red shining mass, endued with an acrid metallic taste, and which is soluble in water, and poisonous. This consists of 200 parts of mercury, and 16 of oxygen. Again, if mercury be rubbed in a mortar with sulphur, it unites with a given proportion. If the mercury be poured into melted sulphur, and strongly heated, a compound will be formed which rises in vapour, and concretes on cooling into a brilliant red substance, known as cinnabar or

vermilion. In this the quantity of sulphur is double of that in the preceding compound. Another compound of mercury is the well-known medicine called calomel, which is formed by the union of the metal with a gas named chlorine. The compound is heavy, white, tasteless, crystalline, and nearly insoluble in water. It may be taken in doses of several grains without any effect but that of a purgative. It is composed of 200 parts of mercury, and 36 of chlorine. If, however, the mercury be made to combine with 72 parts of chlorine, it produces corrosive sublimate, a semitransparent white mass, of an acrid, nauseous, metallic taste, soluble in water and alcohol, and highly poisonous. In these examples, it will be seen that substances comparatively inert, may produce by their union compounds of highly active properties; and that a compound of two bodies, which, in one proportion, if taken internally, will have but a slight effect upon the animal frame, if united in a different proportion will prove destructive to life. On the other hand, highly active bodies of opposite properties will also produce, by their union, substances of a mild character, and they are then said to *neutralise* each other. Sulphuric acid, or oil of vitriol, is highly corrosive, and intensely sour. If brought into contact with any substance stained with vegetable blue colours, as those of violets or litmus, it instantly changes them to a bright red, a property which belongs to all the acids. Barilla, or carbonate of soda, is a solid that is soluble in water, of a hot, acrid, bitter taste. It changes the blue colour of vegetables to green, which property is common to all alkalies. If into a solution of this substance we carefully drop a portion of the former, a brisk effervescence will ensue, and carbonic acid will be given off. If the experiment be performed with care, and the affusion of the acid stopped the moment the effervescence ceases, the solution will be found to be warm, and possessed of properties totally different from those of the acid or alkali from which they have been formed; it will no longer be sour, corrosive, acrid, or hot; it will have no action on vegetable colours, and all the active properties of the original bodies are said to be neutralised. The compound is slightly bitter, saline, and cooling. If part of the water be evaporated by heat, a solid will be deposited in regular crystalline forms, called sulphate of soda, or Glauber's salt. The operation of affinity, which produces chemical composition, exists in a body in different degrees towards other bodies; and if to a compound of two bodies a third be presented which has a stronger attraction for either of the component parts than they have for each other, a decomposition will take place, and a new compound will result. Carbonate of soda is composed of carbonic acid and soda; and in the experiment above referred to, it is decomposed, the sulphuric acid uniting with the soda, and the carbonic acid escaping in the gaseous state. In like manner, if a solution of carbonate of soda be boiled with caustic lime, the carbonate of soda will be decomposed, the carbonic acid will quit the soda and unite with the lime, forming carbonate of lime or chalk, and caustic soda will remain in the solution. These affinities are conveniently represented in the following diagrams:—

$$\text{Carbonate of soda}\quad\left\{\begin{array}{l}\text{Carbonic acid.}\\[1ex] \underbrace{\text{Soda.}\qquad\qquad\text{Sulphuric acid.}}_{\text{Sulphate of soda.}}\end{array}\right.$$

$$\text{Carbonate of soda}\quad\left\{\begin{array}{l}\text{Soda.}\\[1ex] \underbrace{\text{Carbonic acid.}\qquad\qquad\text{Lime.}}_{\text{Carbonate of lime.}}\end{array}\right.$$

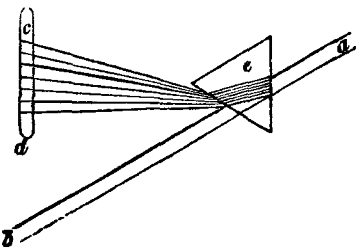
In these diagrams the substance at bottom is the new compound, which is precipitated, or thrown down, and that at the top either escapes or remains in solution; this action is called *single elective affinity*. If two compounds are

brought together in solution, it not unfrequently happens that a process of double decomposition and composition occurs; that is, the two original bodies are decomposed, and two new compounds produced, by a mutual interchange of ingredients: this compound action has been named *double elective affinity*. Decomposition, which cannot be effected by single, may by double elective affinity. Sugar of lead, or acetate of lead, is a compound of acetic acid and lead. White vitriol, or sulphate of zinc, is compounded of sulphuric acid and zinc. If in a solution of acetate of lead we suspend a piece of metallic zinc, we shall have an example of single elective affinity; the acetic acid will act upon the zinc, and the lead will resume its metallic state, and be precipitated on the zinc in a beautiful arborescent form. But if a solution of acetate of lead be mixed with a solution of sulphate of zinc, the acetic acid will unite with the zinc, and, at the same instant, the sulphuric acid will combine with the lead, forming an insoluble precipitate, which will fall to the bottom of the vessel while the acetate of zinc remains in solution. The latter is an instance of double elective affinity, and may be represented by the following diagram:—

$$\begin{array}{ccc} & \overbrace{\text{Acetic acid.} \qquad \text{Zinc.}}^{\text{Acetate of zinc.}} & \\ \text{Acetate of lead.}\left\{\begin{array}{l}\\ \\ \end{array}\right. & & \left.\begin{array}{l}\\ \\ \end{array}\right\}\text{Sulphate of zinc.} \\ & \underbrace{\text{Lead} \qquad \text{Sulphuric acid.}}_{\text{Sulphate of lead.}} & \end{array}$$

Here the original substances are placed on the right and left of the diagram, while the new compounds occupy the top and bottom.

Having given a general view of the nature of chemical attraction, we shall next proceed to sketch the most important facts as connected with this subject relative to light, heat, and electricity. The phenomena resulting from the motion of light will be found in the article Optics; we shall, therefore, in the present sketch, refer to the mechanical properties of light only so far as is necessary to render its chemical effects intelligible. When a pencil of light is admitted through a hole in a window shutter into a darkened room, and made to fall on a triangular glass prism, it is turned out of its natural or straight-lined direction, and prevented from falling on the floor, where it would produce a spot of white light, instead of which it forms a spectrum of splendid colours on the wall, or on a screen placed to receive it. From this circumstance it appears that light is compound and separable by means of an inequality in the refrangibility. In the annexed diagram *a b* represents a ray of light, which falling on the prism *e*, is diverted from its course, and dispersed into colours occupying the space *c d*. The colours, proceeding from the bottom, are red, orange, yellow, green, blue, indigo, and violet, according to Sir Isaac Newton's observation; but some modern observers state that there are only red, green, blue, and violet, in the spectrum, when it is formed as it should be, with a very small pencil of light.



The violet occupying the upper part of the spectrum, is most diverted from its course, and is said, therefore, to be the most refrangible. The red is the least refrangible. This effect is very similar to that of elective attraction, for the same glass acts with different force on different rays; and this analogy is extended by the observation that different kinds of glass, as well as other substances, disperse light in different proportions. If these differently coloured rays of light thus separated by the prism be concentrated on one spot by means of a lens, they will reproduce colourless light. If the spectrum produced, as we have stated, be minutely examined, it will be found to have different properties in different parts. Thus the red end will most sensibly affect the

thermometer; the lightest green rays are most illuminative, and the violet end produces the most decided chemical changes. If the white *luna cornea*, the muriate of silver, be moistened and exposed to the different rays in the prismatic spectrum, it will be found that no effect is produced upon it in the least refrangible rays, which occasion heat without light. A slight discolouration will be occasioned by the red rays, but the blackening power will be greater in the violet than in any other ray; and beyond the violet, in a space perfectly dark, the effect was still perceptible. This observation shows that there are rays more refrangible than those which produce heat and light. Sir H. Davy found that a mixture of chlorine and hydrogen acted more rapidly upon each other, combining without explosion, when exposed to the red, than when placed in the violet rays; but that solution of chlorine in water became solution of muriatic acid most rapidly when placed in the most refrangible rays of the spectrum. He also observed that the puce-coloured oxide of lead, when moistened, gradually gained a tint of red in the least refrangible rays, and at last became black, but was not affected in the most refrangible. The same change was produced by exposing it to a current of hydrogen gas.

Dr. Wollaston found that guaiac, exposed to the violet rays, passed rapidly from yellow to green. MM. Gay Lussac and Thenard applied the same influence to a gaseous mixture of hydrogen and chlorine, when an explosion immediately took place. By placing small bits of card, coated with moist horn silver, or little phials of those mixed gases, in different parts of the spectrum, M. Berard verified the former observations, of the chemical power acquiring its maximum in the violet ray, and existing even beyond it; but he also found by leaving the tests a sufficient time in the indigo and blue rays, a perceptible effect was produced by them also. He concentrated by a lens all that portion of the spectrum which extends from the green to the extreme boundary of the violet, and by another lens he collected the other half of the spectrum, comprehending the red. The latter formed a focus of white light so brilliant that the eye could not endure it, yet in two hours it produced no sensible effect on muriate of silver. On the contrary, the focus of the other half of the spectrum, whose light and heat were far less intense, blackened the muriate in ten minutes. The sun beams, in traversing a coloured glass, produce similar effects. Thus, the chloride of silver acquires a black tint behind a blue or violet glass, but does not blacken behind a red or orange glass. On the other hand, it becomes red behind a red glass, and that much more quickly than even in the solar spectrum. With respect to the light emitted by gases, even the bright light of olefiant gas, when concentrated so as to produce a sensible degree of heat, occasioned no change on the colour of muriate of silver, nor on a mixture of chlorine and hydrogen; while the light emitted by electrized charcoal speedily affects the muriate, and causes these gases to unite rapidly, and sometimes with explosion. Sir H. Davy has remarked, that the refraction and effects of the solar beam offer an analogy to the agencies of electricity. In the voltaic circuit, the maximum of heat seems to be at the positive pole, where the power of combining with oxygen is given to bodies, and the agency of rendering bodies inflammable is exerted at the opposite surface; and similar chemical effects are produced by negative electricity, and by the most refrangible rays of the solar beam. In general, in nature, the effects of the solar rays are very compounded. Healthy vegetation depends upon the presence of the solar beams, or of light; and whilst the heat gives fluidity and mobility to the vegetable juices, chemical effects likewise are occasioned—oxygen is separated from them, and inflammable compounds formed. Plants deprived of light become white, and contain an excess of saccharine and aqueous particles, and flowers owe the variety of their hues to the influence of the solar beams. Even animals require the presence of the rays of the sun, and their colours seem materially to depend upon the chemical influence of these rays; a comparison between the polar and tropical animals, and between the parts of their bodies exposed, and those not exposed to light, shows the correctness of this opinion. Light is produced in several natural operations, most of which may be considered in this place. If two pieces of quartz be rubbed together, light is

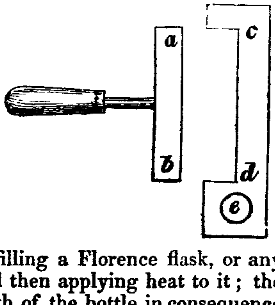
produced even under water. Atmospheric air, or oxygen, quickly and violently compressed in a glass syringe, or a glass ball filled with the latter, and suddenly broken in vacuo, produces light. Light accompanies intense heat. Air heated up to 900° Fahr. and made to fall on pieces of metal, earth, &c. communicates to them the power of radiating light. The flame exhibited in the burning of charcoal and phosphorus is merely the ignition of the solid particles of these bodies. At a certain elevation of temperature, about 800° of Fahr., all solid bodies begin to give out light, and the same effect is produced in vacuo by transmitting voltaic electricity through a metallic wire. The phosphorescence of minerals is another source of light. If fluor spar be coarsely pounded and placed upon a mass of iron heated below redness, it will give out a beautiful green light; this property is possessed by quartz, topaz, phosphate of lime, and a variety of other minerals. There is also a class of bodies called solar phosphoric, which emit light upon exposure to any highly luminous body; the most powerful of these is a compound discovered by Canton. If three parts of calcined oyster shells in powder are mixed with one of flour of sulphur, and the mixture rammed into a crucible, and ignited for half an hour, we shall find that the bright parts, on exposure to the sun-beam, or to the common daylight, or to an electric explosion, will acquire the faculty of shining in the dark so as to render visible the figures on the dial-plate of a watch. After a while they will cease to shine; but if the powder be kept in a well corked phial, a new exposure to the sun-beam will restore the luminescence. When an electric discharge is transmitted along the surfaces of certain bodies, a somewhat durable phosphorescence is occasioned; thus—

Sulphate of barytes gives a	bright green light.
Acetate of potash . . .	brilliant green light.
Succinic acid	ditto, more durable.
Loaf sugar	ditto.
Selenite	ditto, but transient.
Rock crystal	red, and then white.
Quartz	dull white light.
Borax	faint green light.
Boracic acid	bright green light.

Canton's pyrophorous produces more light by this treatment than any other body, but nearly every native mineral, except metallic ores and metals, become luminous by an electric explosion. Light is also emitted in certain chemical changes, where no sensible heat is perceived. Marine animals, both living and dead, emit light; as the shell fish called *pholas*, the *medusa phosphorea*, and other molluscæ. When deprived of life, marine fishes in general seem to abound in this kind of light; among insects, also, several species of *fulgora*, or lantern-fly, and of *lampyris*, or glow-worm. Rotten wood and peat earth also emit light copiously. This luminous matter may be separated from the bodies of animals by immersing them for a short time in dilute saline solutions; one part of sulphate of magnesia in eight of water is the most convenient menstruum for this purpose. Fresh water, spirit of wine, and dilute acids, destroy the luminous property altogether, while a gentle heat, and oxygen gas, increase the brightness of the phosphorescence.

The next important agent in chemical investigations is *heat*. Many chemists have considered heat or caloric as a material substance, capable of entering into combination with all other kinds of matter; but recent investigations seem to put it and light upon the same ground, and show them to be but certain states of matter, brought about by the undulations of an exceedingly subtile ether, which is considered to fill all the space in the universe not occupied by other matter. Heat appears to be an antagonist principle to attraction; while the latter binds together, the former tends to separate, the parts of bodies, first expanding them, then reducing them to the liquid state, and finally to that of gas or vapour. Sometimes it decomposes a body, separating it into its proximate or ultimate elements: so powerful, indeed, is heat, as a repulsive

agent, that there can be no doubt that, if the temperature of the globe were sufficiently increased, every solid mass on its surface would become liquid, and every liquid assume the state of vapour. We have an illustration of this consequence in the different states of the same body on different parts of the earth's surface. Thus some bodies, as butter, oil, water, &c. which exist only as solids at the poles of the earth, are perfectly liquid at the equator. Ether, which is a liquid in this latitude, can only exist as a vapour in the torrid regions of the earth. Mercury also, which we see always in the liquid state, may, by exposure to the intense cold of a northern sky, be converted into a solid metal like lead. The most immediate and general effect of heat is expansion. If a poker or an iron ball be placed in a fire, it becomes heated, and assumes that state which is called ignition; at which time its temperature is nearly equal to that of the surrounding fuel. In like manner, if a cup of cold water be placed within a vessel of hot water, the two speedily become of the same temperature, the one giving out caloric, and the other receiving it. If now either of these bodies that have changed their temperature be examined, it will be found to have changed its bulk also. This expansion of bodies by heat, and their consequent contraction by cold, are facts of the highest importance in the arts. The amount of expansion in different substances by a known increase of temperature, has therefore been carefully studied, and a variety of results, more or less accurate, have been obtained by different experimentalists. The property of expansion by heat, and contraction by cold, appears to belong to nearly all bodies upon which experiments have been made; at least in that class of bodies which compose the mineral kingdom, for among vegetables the effects of heat are so mixed with other effects, that it is difficult to distinguish them. Some minerals, too, as clay, and several metallic substances, have been considered as exceptions to the general law; but a more minute investigation has shown that they are only apparent. Clay contracts in consequence of the expulsion of moisture, and the incipient fusion that occurs; and some of the metals, as iron, bismuth, antimony, in fusion, expand in the act of setting or solidifying, but afterwards contract as they cool. The force with which bodies expand is so great as to overcome every resistance that is opposed to it. The general fact of the expansion of solid bodies by heat may be seen by taking a metal cylinder *a b* that will just fit into a gauge *c d*, and pass through a circular hole *e* when cold. When made red hot, it will be found so much enlarged as to be incapable of passing through the hole, or fitting into the gauge, thus proving that it has been enlarged in all its dimensions. The cubic or solid expansion is always three times greater than the linear. For example, if the expansion of a rod of steel be one-tenth of its length, the whole expansion will be three-tenths of its bulk. The



expansion of liquids may be made evident by filling a Florence flask, or any bottle with a narrow neck, with cold water, and then applying heat to it; the fluid will soon be observed to flow over the mouth of the bottle in consequence of its increased bulk. This fact is also familiarly illustrated by means of an ordinary tea-kettle, which, if it be quite filled with cold water, will be unable to contain the increased bulk occasioned by heat, and will consequently discharge a portion of its contents over the hearth long before the water reaches its boiling point. The expansion of air may be shown by a similar apparatus. If the flask full of air be inverted with its mouth under water, and the flame of a lamp or candle be applied to it, the air will be expanded, and will be seen escaping from the mouth of the flask in large bubbles. If the flame be removed, the air will cool, gradually contract its dimensions, and the water will rush up into the vessel to fill the space vacated by the air. The expansion of solid bodies is ascertained by what is called a pyrometer, for the construction of which see its name. The most general facts connected with expansion are as follows:—1. Nearly all solids, liquids, and gases, are expanded by heat, and

contracted by cold; and of these, the gases are most expansible, and solid bodies least. 2. Different solids and liquids are differently expanded by the same degree of heat, but gases and vapours are equally and equably expanded by equal portions of heat. 3. In the same body, whether solid or liquid, the expansion by a given quantity of heat, is greater at higher than at lower temperatures; but in gases and vapours, the expansions are equal, by equal additions of heat at all temperatures. 4. The expansion of atmospheric air, gases, and vapours, not in contact with the liquids from which they have been generated, is equal to one four hundred and eightieth part of the bulk they occupy at 32° of Fahrenheit's thermometer. The absolute dilatation in length of several of the most generally used substances, is shown in the following table:—

Glass tube	$\frac{1}{1148}$	Brass	$\frac{1}{535}$
Platina	$\frac{1}{1131}$	Silver	$\frac{1}{524}$
Iron	$\frac{1}{846}$	Tin	$\frac{1}{462}$
Steel	$\frac{1}{807}$	Lead	$\frac{1}{351}$
Gold	$\frac{1}{682}$	Zinc	$\frac{1}{340}$
Copper	$\frac{1}{582}$		

Glass from 32° to 212° of the thermometer	$\frac{1}{116}$
Ditto 212 to 392	$\frac{1}{1089}$
Ditto 392 to 572	$\frac{1}{987}$

Expansion of liquids in bulk.

Alcohol	$\frac{1}{9}$	Muriatic acid (sp. gr. 1.137)	$\frac{1}{17}$
Nitric acid (sp. gr. 1.4)	$\frac{1}{9}$	Water saturated with salt	$\frac{1}{20}$
Fixed oils	$\frac{1}{12}$	Water	$\frac{1}{22}$
Oil of turpentine	$\frac{1}{14}$	Mercury	$\frac{1}{55}$
Sulphuric ether	$\frac{1}{14}$	Apparent expansion of mercury in glass	$\frac{1}{64}$
Sulphuric acid (sp. gr. 1.85)	$\frac{1}{17}$		

One of the most important applications of the expansibility of liquids, is in the construction of the thermometer, which consists essentially of a closed tube, containing a liquid, the expansion of which can be conveniently observed. To construct a thermometer, a glass tube of very small bore is usually taken, and a bulb, globular, cylindrical, or conical, is blown at one end, which bulb and part of the tube are then filled with perfectly pure mercury. The tube must then be hermetically sealed by melting the top by means of a blow-pipe flame. Previous to closing the top, however, the mercury must be exposed to heat so as to completely fill the tube; and while the tube is full, the sealing must be effected. When the mercury cools, the surface will subside, and a vacuum will be left in the upper part of the tube. The thermometer is then complete, except its graduation; this is accomplished as follows:—The bulb is to be plunged into snow or ice that is just melting, and a mark made on the tube at the point at which the mercury stands; this is called the *freezing point;* and in the thermometers common in this country, called Fahrenheit's (from the inventor's name), it is marked 32°. The tube must next be placed in boiling water, or its steam, in such a way that the whole of the mercury may be exposed to heat. When the mercury has risen and is stationary, another mark must be made; this denotes the *boiling point* of water, and is marked 212°. The space between the boiling and freezing points must next be divided into 180 equal parts, and the graduation is complete. In the centigrade thermometer used in France, the freezing point is marked 0°, and the boiling point 100°, the intervals being

divided into 100 equal parts or degrees. One degree of Fahrenheit is therefore equal to four-ninths of the centigrade; and one of the centigrade to nine-fourths, or $2\frac{1}{4}^{\circ}$ Fahrenheit. This is but a brief and general view. For further information, see THERMOMETER.

It has been already stated that fluidity is the result of heat. Every solid may be liquefied; and many of them, as well as liquids, may be vaporized at a certain elevation of temperature; and there can be little doubt that every known liquid may be solidified if we possessed the means of sufficiently reducing the temperature. Several of the gases, by the united operation of cold and pressure, have already been reduced to the fluid state, and nearly every known liquid may be frozen. The temperature at which a solid body assumes the liquid state is called its fusing or melting point. If the substance be ordinarily in the liquid state, this point will be its freezing, concreting, or congealing point. The concreting or congealing temperatures of various substances will be found in the following table:—

	Deg.		Deg.
Sulphuric ether	46	Sulph. and phos., equal parts	40
Liquid ammonia	46	Sulphuric acid (sp. gr. 1.78) .	46
Nitric acid (sp. gr. 1.424) .	45.5	Tallow	92
Ditto (sp. gr. 1.329) .	2.4	Phosphorus	108
Sulphuric acid (sp. gr. 1.8376)	1	Spermaceti	112
Common salt 25 + water 75 .	4	Potassium	136.4
Ditto 22.2 + ditto 77.8.	7.2	Yellow wax	142
Oil of turpentine	14	White wax	155
Strong wines	20	Sodium	194
Blood	25	Sulphur	218
Common salt 4.16 + water 9.584	27.5	Tin	442
Milk	30	Bismuth	476
Water	32	Lead	612
Olive oil	36	Zinc	680

The temperature at which bodies melt is fixed, but the congealing point is modified by circumstances. Many liquids may be cooled considerably below their usual freezing points, before they assume the solid state. This is the case with water, which may be cooled 10°, or even 20° below its congealing point without freezing; but if a small spicula of ice be dropped into it, or the water caused to vibrate, it will instantly solidify. The same phenomena occur with saline solutions. A hot saturated solution of sulphate of soda may be cooled to 50° under a film of oil, and it will remain liquid, and bear to be moved about in the hand without any change; but if the vessel containing it be placed on a vibrating table, crystallization will instantly take place. One remarkable fact attends the cooling of bodies below their usual freezing point; viz. at the instant solidification occurs, the temperature of the mass rises to the proper freezing point. Thus, if a portion of water be placed in an atmosphere of 21°, the liquid will cool and remain fluid at this temperature, till, by touching it with a piece of ice, or causing it to vibrate, we make it freeze, when it instantly rises to 32°, or 11° above the surrounding medium. This curious fact was first explained by Dr. Black, and gave rise to the knowledge of the latent heat or caloric of fluidity of bodies. Dr. Black suspended two glass globes, of the same size, near each other; the one filled with ice at 32°, the other with water at 33°: in half an hour the water had risen to 40°, but it took ten hours and a half to liquefy the ice, and heat the resulting temperature to 40°. In this experiment we observe that 7° of heat entered the globe in 1 half-hour, but 21 half-hours were required to melt the ice and raise its temperature to 40°. If from the product $7 \times 21 = 147^{\circ}$, we subtract 7°, which the water was above 33°, we have 140° as the measure of a quantity of heat that has entered the substance without being appreciable by the thermometer. Another simple experiment, showing the same result, is made by mixing a pound of pulverized ice at 32°, with a pound of water heated to 172°; the ice is instantly melted, but the temperature is only 32°. Here, then, 140° of heat have disappeared without raising the temperature. From this circumstance, the quantity of heat that

always disappears when a body assumes a fluid state, is called *latent heat*, or caloric of fluidity. The latent heat of different substances varies, as may be seen in the following table by Dr. Irvine:—

Sulphur	143.68	Zinc	493
Spermaceti	145	Tin	500
Lead	162	Bismuth	550
Bees' wax	175		

The quantity of heat that disappears in the liquefaction of solids, explains the origin of that cold which always accompanies solution, and enables us to apply the process of artificial cooling by what are termed freezing mixtures. Snow and salt, when rapidly mixed, dissolve and produce a reduction of temperature equal to 38°. The more rapid the liquefaction the greater the cold; hence, if the snow and salt be placed in a pan over the fire, and a glass tube containing water be immersed in it, the water in a few seconds will be found frozen. The solution of all crystallized salts is attended with a depression of temperature, which in general increases with the solubility of the salt; the like occurs with certain metals. If a solid amalgam of bismuth be mingled with a solid amalgam of lead, they become fluid, and the thermometer sinks. A variety of experiments have been made on the frigorific effects of different mixtures, some of which are stated in the following table, abridged from Mr. Walker's *Experiments on Frigorific Mixtures.*

1. *Frigorific Mixtures without Ice.*

Mixtures.	Parts.	Thermometer sinks.	Degree of cold produced
Muriate of ammonia . . Nitrate of potash . . . Water	5 5 16	From 50° to 10°.	40
Sulphate of soda . . . Diluted nitric acid . . .	3 2	From 50 to 3.	53
Nitrate of ammonia . . Water	1 1	From 50 to 4.	46
Sulphate of soda . . . . Diluted sulphuric acid . .	5 4	From 50 to 3.	47
2. Frigorific Mixtures with Ice.			
Snow or pounded ice . . Muriate of soda	2 1	From any temperature to 5.	
Snow . . . . Diluted nitric acid . . .	7 4	From 32 to 30.	62
Snow . . . . Muriate of lime	4 5	From 32 to 40.	72
Snow . . . . Muriate of lime	2 3	From 15 to 68.	53
Snow . . . . Diluted sulphuric acid . .	8 10	From 68 to 91.	23

Similar phenomena to those that take place in liquefaction, occur in vaporizing any liquid. If a vessel of water be placed over the fire, a sound is pro-

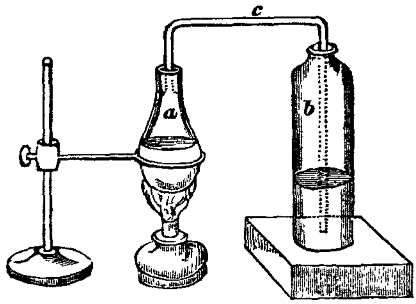
duced by the successive vaporization and condensation of the particles in contact with the bottom of the vessel. As the liquid increases in heat, the sound becomes louder till it terminates in ebullition. At this point the temperature ceases to rise, and remains stationary till the whole of the liquid is evaporated. To ascertain the quantity of heat consumed in vapourizing a given quantity of water, Dr. Black set a tin cup full of water at 50° on a red hot iron plate; in 4 minutes it reached the boiling point, and in 20 minutes more it was all boiled off. From 50° to 212° the rise is 162°, which was gained in 4 minutes; but it took five times as long to be converted into vapour; hence $162 \times 5 = 810°$ is the quantity of heat that disappears, or is rendered latent in the conversion of water into steam. By subsequent experiments, the latent heat of steam is found to be 967°, or 1,000°. The point at which liquids emit vapour of equal tension with the atmosphere, which is their true boiling point, differs in different liquids, as may be seen in the following table:—

	Boiling points.
Ether (spec. grav. 0.7365, at 48°)	100
Alcohol (spec. grav. 0.813)	173.5
Nitric acid (spec. grav. 1.500)	210
Water	212
Saturated solution of sea salt	224
Muriatic acid (spec. grav. 1.094)	232
Ditto (spec. grav. 1.16)	220
Oil of turpentine	316
Sulphuric acid (spec. grav. 1.3)	240
Ditto (spec. grav. 1.848)	600
Phosphorus	554
Sulphur	570
Linseed oil	640
Mercury	656

The boiling point of the same liquid varies with the atmospheric pressure, and also with the vessel the liquid is boiled in. Thus, in silver, the boiling point was found to be 211.775°, in common earthenware, 213.8°, at the mean pressure of the atmosphere. If the whole of the pressure be removed, liquors will boil and assume the vaporous state at 124° below their ordinary boiling points. Thus water will boil in vacuo at 88°, instead of 212°; and alcohol, at 49°. On this principle Dr. Wollaston constructed his thermometric barometer, for measuring heights. He found that a difference of 1° in the boiling point of water is occasioned by a difference of pressure equal to 0.589 of an inch on the barometer. If water be heated in a close vessel, or under extraordinary pressure, its temperature may considerably exceed 212°; and as the steam will be always of the same temperature as the liquid, and will have its elasticity increased by heat, the vapour produced will considerably exceed the atmosphere in elasticity, giving rise to what is called *high pressure* steam. At the freezing point of water, the vapour that rises will have sufficient elasticity to balance two-tenths of an inch of mercury in the barometer; at 212° it equals the atmospheric pressure (about 30 inches). Its elasticity at some other temperatures is stated in the following table:—

Temperature.	Pressure.
40	0.25 inches.
80	1.01
100	1.86
135	5.07
170	12.05
205	25.00
212	30.00 = 1 atmosphere.
248	60.00 = 2 ditto.
273	90.00 = 3 ditto.
290	120.00 = 4 ditto.
305	150.56 = 5 ditto.

A pint of water at 40°, on being converted into steam, forms 1,694 pints; or in round numbers, 1 cubic inch of water will form 1,728 inches, or 1 cubic foot of steam. We have already observed that the latent heat of steam is about 1,000°. This may be ascertained by evaporating a given weight of water, and condensing it into a known weight of cold water. This may be illustrated by an apparatus similar to the annexed cut. A given weight of water may be evaporated from the vessel *a*, the vapour of which will pass along the pipe *c*, and be condensed in the water in *b*. It will be found that the steam will raise the temperature of the water in *b* six or seven times more than an equal weight of boiling water would do. By experimenting in this manner, Dr. Ure has ascertained the latent heat of several vapours, as in the annexed table:—



		Latent heat.
Vapour of	water at its boiling point	1000
„	alcohol (spec. grav. 825)	457
„	ether (boiling point 112) . . .	312.9
„	petroleum	183.8
„	oil of turpentine	183.8
„	nitric acid (spec. grav. 1.494) . .	550
„	liquid ammonia (spec. grav. 0.978) .	865.9
„	vinegar (spec. grav. 1.007) . . .	903

From the above table it will be seen that different bodies require different quantities of heat to enable them to assume the vaporous state. An analogous fact is, that different bodies require very different quantities of heat to elevate their temperatures a given number of degrees. If a pound of water at 60° be mixed with a pound of oil at 90°, the resulting temperature will be 70° instead of the mean 75°. And conversely, if a pound of water at 90° be mixed with a pound of oil at 60°, the temperature of the mixture will be 80°. In the first experiment we see that the oil lost 20°, while the water only acquired 10°; and in the second the oil gained 20°, while the water lost only 10°. Hence the specific heat of water is double that of oil; or the same quantity of heat that will raise the temperature of oil 20°, will only raise that of water 10°. The same fact may be shown by placing mercury, oil, and water, in an oven; the mercury will be first heated, next the oil, and lastly, the water. An important practical illustration of the doctrine of specific heat is afforded by atmospheric air. The specific heat of air diminishes more slowly than its specific gravity. When air is expanded to a quadruple volume, its specific heat is 0.540; and when expanded to eight times the volume, its specific heat is 0.368. The densities 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, correspond nearly to the specific heats 5, 4, 3, 2. Hence may be explained the intense cold that prevails at the tops of high mountains, and also the great heat developed in the compression of gases. A compression equal to four-fifths is sufficient to ignite tinder; and if a syringe of glass be used, a vivid flash of light is seen to accompany the compression.

We have now alluded to most of the phenomena of heat that may be useful in chemical investigations, except those which relate to the conduction and radiation, which we shall briefly illustrate.

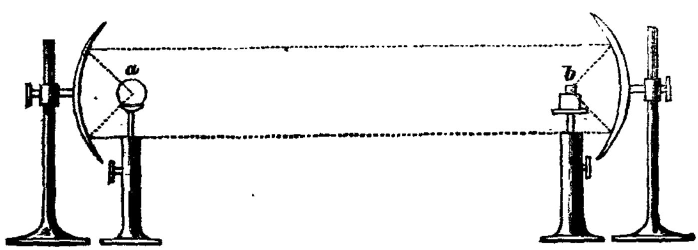
It is well known that if a bar of iron, as a poker, be placed in the fire, the heat will in time be communicated to its remote end. It is also a matter of common observation, that a hot mass of iron, or a vessel of hot liquid suspended in a room, will gradually become cooler until it attains the temperature of the surrounding medium. If we suppose a mass of iron, heated red hot, to

be placed on a metallic pillar or support, in a still room, we shall find that it will lose its heat in three distinct ways. 1. If the metallic support be felt, it will be found to be hot, and we may consequently infer that a portion of the heat has been conducted away by its means. 2. If the hand be held over the hot body, considerably above it, a current of hot air will be perceived, which must convey another portion of caloric from the hot body. 3. If the hand be held at some distance from the side of the body, a distinct sensation of heat will be experienced; and as this occurs when the hot body is inclosed in a vessel exhausted of its air, it is manifestly a different mode of cooling from the other two: in fact, a variety of experiments render it evident that the heat is projected from the hot body in right lines on every side. In the first of these modes of cooling, the heat is conducted slowly along the iron bar, which is denominated a conductor; and the process is called the *conduction of heat.* In the second, the heat unites with the particles of air, and renders them specifically lighter, in consequence of which they ascend, and another stratum of cooler particles descend and occupy their place; these in their turn become expanded and rise, and thus a constant ascending current is maintained. Caloric, therefore, is conducted from bodies in two ways; it either imparts heat to the adjacent particles, which impart it to the next, and so on, without change of place, or it unites with the adjacent particles of the surrounding medium, and is conveyed upwards by the increased levity which it occasions. The third method of cooling in which the caloric is projected from the body in right lines, is called the radiation of caloric. The communication of heat by contact is manifest in solids and liquids, although in the latter it is chiefly propagated by the ascent of heated particles. If different solids be taken, and have one end exposed to a high temperature, one of them will become heated in a shorter time than another. Thus, if a piece of copper or iron wire, 3 or 4 inches long, be held in the hand by one end, while a spirit lamp is applied to the other, it will soon become so hot as to be intolerable; while a glass tube, in similar circumstances, may be held within an inch of the flame with little inconvenience. The difference in the facility with which heat is transmitted through bodies, will appear from the following table:—

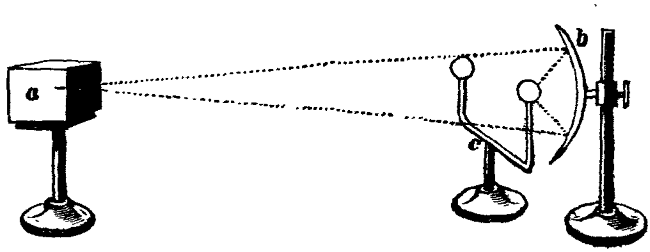
	Conducting power.		Conducting power.
Gold	100	Tin	30
Platinum	98	Lead	18
Silver	97	Marble	2.5
Copper	89	Porcelain	1.25
Iron	37	Brick earth	1
Zinc	36		

From this table it appears that the metals are the best conductors of heat, though even among them there are striking differences. The different kinds of wood have very little conducting power, and hence are well adapted for handles to vessels that are exposed to heat. Bodies of a porous or spongy nature, especially fibrous substances, as wool, silk, feathers, fir, &c. are the worst conductors of heat; and from this circumstance derive their value as articles of clothing. It is, however, probable that the warmth of these substances is attributable rather to the impediments they offer to the motion of the air than from any inherent heat-retaining power. Confined air is a bad conductor of heat; and if a quantity of it be enclosed among the interstices of the fur, wool, &c. it will furnish an effectual barrier to the egress of caloric. On this account double windows and doors are found effectual in maintaining an equable temperature in our apartments. The conducting power of liquids by contact is so exceedingly small, that for a long time it was doubted whether they conducted at all. Accurate experiments made in vessels of ice, have, however, established the fact that liquids do conduct heat downwards, or by contact of their particles. If it be desirable to heat a liquid, it is well known that the heat should be applied at the bottom of the vessel, by which means the stratum of particles nearest the fire becomes lighter, and ascends, being forced up by the descent of

the colder, and therefore heavier parts. This process continues until the whole has attained that degree of heat at which the liquid boils; the same occurs in heating a confined portion of air. Any circumstance that tends to impede the motion of the particles of liquids will diminish the facility with which they are heated or cooled. Water-gruel, soups, and other thick drinks, retain their heat for a considerable time; while more dilute liquids become cooled at the surface, the cooler parts subside, and the hot ones rise and come into contact with the atmosphere; these become cooled and sink, and thus the process goes on till the whole attains the same temperature as the surrounding medium. It has been long known that the sun's rays proceed in right lines, and that they are capable of being reflected and refracted by mirrors and lenses so as to produce an intense heat. In like manner, if an iron ball be heated a little below redness, it will be found to emit rays of heat that are capable of being reflected and refracted in a similar way. If two concave and polished metallic mirrors be placed opposite to each other, and at about eight or ten feet distant, (as in the annexed engraving,) and the hot iron ball be placed in the focus of one, as at *a*, while in that of the other we place a piece of phosphorus *b*, resting on a lump of charcoal, or any bad conductor, in a few seconds the



phosphorus will inflame. Now to produce this effect, it is manifest that rays of heat must have emanated from the iron ball, and falling on the nearer mirror, must have been reflected to the second mirror, by which they have been concentrated on the phosphorus. In this experiment we observe two important facts, the *radiation* and *reflection* of heat. Radiation may be considerably modified so as to be nearly destroyed by an alteration of the surface of the radiating body. Instead of the hot ball, Sir John Leslie used a tin cubic cannister filled with hot water; and as a large body would stop the return of the rays, he used only one mirror, in the focus of which he placed one of the balls of his differential thermometer, as here represented. Previous to placing the cubic canister *a* before the mirror *b*, its four vertical sides were coated with different substances—one with lamp-black, another with China ink, a third with



isinglass, while the fourth was left naked, presenting a surface of polished tin. When this vessel, filled with hot water, was presented to the mirror, the thermometer *c* immediately indicated an increase of temperature, varying according to the surface presented; the lamp-black surface depressed the liquid of the

thermometer 100°, the China ink 88°, the isinglass 80°, and the tin 12°. By a variety of similar experiments, Professor Leslie obtained the results in the following table:—

	Radiating power.		Radiating power.
Lamp black	100	Isinglass	80
Water (by estimate)	100	Plumbago	75
Writing paper	98	Tarnished lead	45
Resin	96	Mercury	20
Sealing wax	95	Clean lead	19
Crown glass	90	Iron polished	15
China ink	88	Tin plate	12
Ice	85	Gold, silver, copper	12

The nature of the substance is not the only circumstance that influences radiation. In general, the more smooth and polished the surface, the more feeble in its radiating power. If the surface be roughened with a file, or otherwise, its radiation is increased. It also appears that the radiation occurs not only from the superficial particles, but also from those immediately beneath them. With one coating of jelly it was found that the radiation was 38°; while a film of the same substance, four times thicker, produced a depression of 54°. When the thickness of the coating amounted to one-thousandth part of an inch, the radiation became diminished. If the same radiating surface be presented to different mirrors, we shall discover the differences in the reflective powers. By various experiments of this kind, the reflective powers of several substances were found to be as follows:—

	Reflective power.		Reflective power.
Brass	100	Tin foil softened with mercury	10
Silver	90	Glass	10
Tinfoil	85	Ditto coated with wax or oil	5
Black tin	80		
Steel	70		
Lead	60		

If we compare these tables, we shall find generally that the best radiators are the worst reflectors, and *vice versâ*. It may easily be inferred, that those bodies that radiate most caloric, when heated above the temperature of the surrounding medium, will also absorb most rapidly when exposed to a temperature superior to their own. In the experiment with the lamp-black surface exposed to the mirror, the thermometer indicated a temperature of 100°; if, however, the glass ball of the thermometer be covered with tin foil, the indication will be reduced to 20°. In the same manner, if the bright side of the canister be presented, the temperature will be 12°, but with the bulb covered, only 2½°. From these experiments, as well as from reasoning, it is evident that the absorptive power is equal to the radiating. Connected with this part of the subject is the effect of screens. When a thin deal board was placed between the canister and the focal ball, the thermometric effect was diminished, and this diminution was proportional to the thickness of the screen. A pane of glass interposed reduced the effect of radiation from 100° to 20°. The reduction was greatest when the screen was most distant from the canister: the thinnest gold leaf stopped the whole of the heat; in general, those bodies intercept heat most effectually which are the worst radiators. From some more recent experiments of M. de la Roche, it is found that caloric acquires a more penetrating power as it proceeds from a source of higher temperature. A curious experiment was made by the Florentine Academicians, in which, instead of the hot canister, a large mass of snow was placed before the mirror: in this case the thermometer indicated a rapid depression of temperature, and it was at first inferred that rays of cold emanated from the snow and acted on the thermometer; this supposition is, however, unnecessary, for it may easily be shown that all bodies radiate heat constantly. Even a mass of ice or snow may have its temperature higher than the surrounding air, and will, therefore, produce signs

of heat in the thermometer. In the experiment just cited, the snow radiates caloric towards the mirror, and the thermometer, at the same time, radiates towards it, which is reflected towards the snow. If the snow were not placed in front of the mirror, the thermometer would receive as much caloric as it emits, and hence its temperature would remain constant; but as the temperature of the snow is lower than that of the thermometer, the latter receives less than it imparts, and its temperature falls.

Having stated the most important general facts connected with heat, we must refer the reader to other articles in the work for more particular information, under the words Expansion, Thermometer, Pyrometer, Combustion, &c. and proceed to another important agent in chemical research—electricity.

If a glass tube, or a stick of sealing-wax, be briskly rubbed with a dry silk handkerchief, and then presented towards small pieces of paper, feathers, or gold leaf, it will first attract and then repel them. Or if a glass tube be taken in one hand, and a stick of sealing-wax in the other, and each be rubbed, then if the glass rod be brought near a piece of gold leaf floating in the air, it will first attract, and afterwards repel it. While the gold leaf is repelled by the excited tube, if the sealing wax be brought near, the leaf will be attracted, and thus it will be seen that bodies electrified by glass will be attracted by the wax, and *vice versâ*. Bodies that are electrified by glass are said to be positively or vitreously electrified; and bodies submitted to excited wax are called negatively, or resinously electrified. If either of the tubes are well excited, and a finger be presented to it, a crackling noise will be heard, and in the dark, sparks of light will be seen issuing from the tube; these are termed electric sparks. If to the further end of the excited tube a brass ball be attached by a wire, the ball will possess all the qualities of the tube itself; but if it be connected by means of silk, the electric virtues will not pass into it. From this circumstance bodies have been divided into conductors and nonconductors. Some bodies conduct or permit the passage of electricity more readily than others; hence arises the distinction of good and bad conductors. The following table contains a list of conducting substances in the order of their conducting power.

Copper.	Dilute acid.
Silver.	Saline solutions.
Gold.	Animal fluid.
Iron.	Water.
Tin.	Ice and snow above 0°.
Lead.	Living vegetables.
Zinc.	Living animals.
Platinum.	Flame.
Charcoal.	Smoke.
Plumbago.	Vapour.
Strong acid.	Salts.
Soot, and lamp black.	Rarefied air.
Metallic ores.	Dry earths.
Metallic oxides.	Massive minerals.

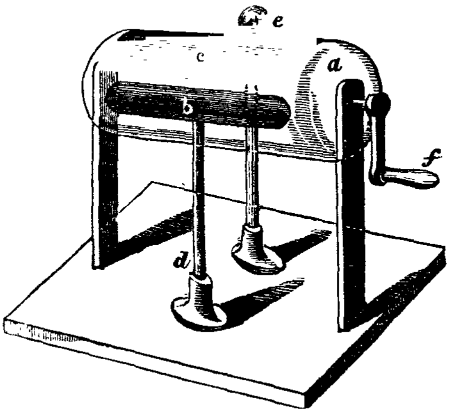
The nonconductors or insulators are as follows:—

Shell lac.	Dry paper and leather.
Amber.	Dry woody fibre.
Resins.	Porcelain.
Sulphur.	Marble.
Wax.	Massive earthy minerals.
Asphaltum.	Camphor.
Glass, and all vitrified bodies.	Caoutchouc.
Raw silk.	Dry chalk and lime.
Bleached silk.	Phosphorus.
Dyed silk.	Ice (below 0° Fahr.)
Wool, hair, and feathers.	Oils; the densest are the best.
Dry gases.	Dry metallic oxides.

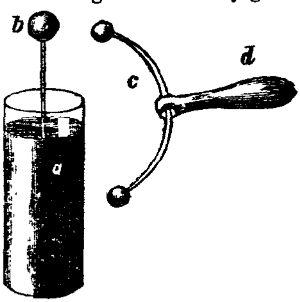
The worst insulators differ very little from the worst conductors, so that the whole list, from copper to shellac, might be considered as one series, in which different degrees of resistance are opposed to the passage of electric power. The best conductors are sometimes called *nonelectrics*, and the best insulators *electrics*, on the supposition that only the latter were capable of producing electricity by friction. This appears to be erroneous, as even metallic bodies may be excited if they are held by a nonconductor to prevent the electricity being carried away as soon as produced. A similar mistake was originally made with respect to the production of vitreous or resinous electricity. It was thought that the same body always produced the same kind of electricity; but it is now known that this depends on the nature of the rubber. In all cases where two bodies are rubbed together, if the one become vitreously electrified, the other will be resinously electrified. In the following table the several substances acquire vitreous electricity when rubbed with those which follow them, and *resinous* when rubbed with those that precede them: —

The skin of a cat.	Paper.
Polished glass.	Silk.
Woollen stuff, or worsted.	Lac.
Feathers.	Roughened glass.
Dry wood.	

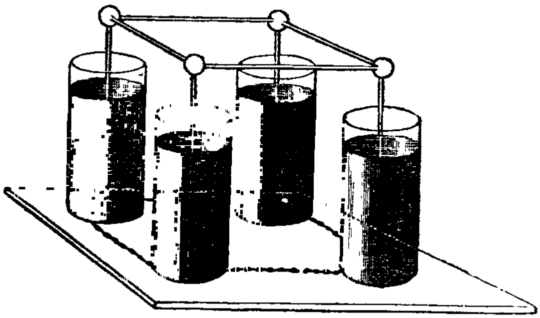
The early experimenters used only the glass tube for the excitation of electricity; but the labour and insufficiency of this process soon gave rise to a machine for the same purpose. There are two kinds of electrical machines now in use, which are called the *plate machine*, and the *cylinder machine*. The cylinder machine is shown in the annexed figure, in which *a* is a cylinder of glass, mounted in a frame, so as to be turned on its axis by means of the handle *f*. At *e* is a cushion stuffed with wool or horse-hair, and covered with an amalgam of three parts of mercury, two of zinc, and one of tin, melted together. Attached to the cushion is a piece of silk *c*, which reaches over the cylinder as far as the prime conductor *b*. The prime conductor *b* is a cylinder of tin or brass, mounted on a glass leg *d*, and furnished with a row of points extended towards the cylinder, for the purpose of collecting the electricity generated by the friction of the cylinder against the rubber.



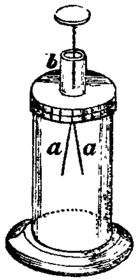
The cushion is mounted on a glass leg for the purpose of procuring resinous electricity; but when only vitreous electricity is required, a chain or piece of wire must be attached to the cushion. The principle of the plate machine is precisely similar to this; but, instead of a cylinder, a circular glass plate is mounted, so as to turn on an axis passing through its centre, while the rubbers are applied near its circumference. When a greater quantity of electricity is required than can be furnished by sparks from the prime conductor, an apparatus is used, which, from having been discovered at Leyden, is called the Leyden Jar. In the engraving *a* represents



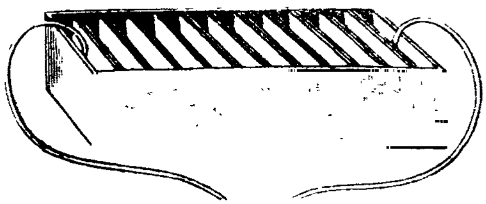
a glass jar coated within and without with tin foil, except near the top; *b* is a brass ball connected with the interior coating by means of a brass wire. When the knob *b* is brought near the prime conductor of the electrical machine, sparks pass into the jar, until it has become charged. A discharging rod *c*, furnished with a glass handle *d*, is then applied, so that one ball touches the outer coating, and the other the brass ball *b*; the whole of the electricity then passes from the inside to the outside of the jar, which is then said to be discharged. If, instead of the discharging rod, a person applies his hands to the outer and inner sides of the jar, the electricity passes through him, and he receives an *electric shock*. If the electricity be accumulated in a large jar, or if several jars are connected, as in the accompanying sketch, they form an electric battery, and all the effects



produced by lightning may be imitated by means of it. If electricity be passed through resin, phosphorus, ether, gunpowder, &c. it inflames them; it will penetrate a thick card or a quire of paper; and if in sufficient quantity, will destroy life in an eel, rabbit, dog, &c. Friction is not the only means of producing electric indications, but it is the most energetic; and when we have occasion to test the presence of electricity excited by other means, it is necessary to use a delicate electrometer. One of these, called Bennet's electrometer, shown in the accompanying sketch, consists of two small slips of gold leaf suspended by a brass wire within a glass cylinder. In the improved form of the instrument the wire which carries the leaves *a a* passes through a plug of silk within a glass tube *b* in the cap of the electrometer. By this instrument we are enabled to perceive that electricity is excited in the fusion of inflammable bodies, in evaporation, in the disengagement of gas, by the sudden disruption of a solid body, by change of temperature, by contact of dissimilar bodies. This latter has been considered by Volta and others as the origin of voltaic electricity, while some of our first chemists consider chemical action to be the primary source of voltaic energy. Voltaic electricity is usually procured by an arrangement of copper and zinc plates, called a voltaic battery. There are different forms of this apparatus, but the battery of Cruikshank is, on the whole, the most convenient.



This consists of a number of zinc and copper plates, soldered together at their edges, and cemented into grooves in the sides of a mahogany trough. To prepare the battery for action, a liquid consisting of about two parts of sulphuric acid, one of nitric



acid, and 100 of water, should be poured into the cells till they are nearly full; a wire must then be inserted at each end touching the outer plates. The wire connected with the zinc plate will give off positive electricity, and the wire attached to the copper plate, negative electricity. The galvanic or voltaic battery is a highly important agent in chemical research, both from its energetic decomposing power, and from the intense heat which it produces. If the two wires are of platinum or gold, and are inserted into a glass of water, the water will be decomposed into its elements, oxygen and hydrogen; the oxygen will appear at the positive wire, and the hydrogen at the negative If the ends of the wires dip into two separate glasses of water, and a finger of each hand be immersed in them, a slight electric shock will be felt, the intensity of which will increase with the number of plates. If the number of plates is very great, or if of large dimensions, the phenomena are beautiful and striking. The battery of the Royal Institution, used by Sir H. Davy, in his researches, contained 2,000 pairs of plates, containing a surface of 128,000 square inches. When pieces of charcoal about an inch long, and one-sixth of an inch in diameter, were brought within one-thirtieth or one-fortieth of an inch of each other, a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness; and by drawing back the points a little from each other, a constant discharge took place through the heated air, in a space equal at least to four inches, producing a most brilliant ascending arch of light, expanded and conical in the middle. When any substance was introduced into this arch, it instantly became ignited. Platinum melted in it like wax in the flame of a common candle. Quartz, the sapphire, magnesia, lime, all entered into fusion. Fragments of diamond, and points of charcoal and plumbago, rapidly disappeared and seemed to evaporate in it, even when the connexion was made in a receiver exhausted by the air pump; but there was no evidence of their having previously undergone fusion. Copper and zinc are not the only metals proper for forming a galvanic battery, but they are the least expensive. The following tables by Sir H. Davy will furnish a variety of combinations. The metal first named is positive in reference to those that follow.

With Ordinary Acids.

Potassium and its amalgams; barium and its amalgams; amalgam of zinc; zinc; amalgam of ammonium, cadmium, tin, iron, bismuth, antimony, lead, copper, silver, palladium, tellurium, gold, charcoal, platinum, iridium, rhodium.

With Alkaline Solutions.

The metals of the alkali, and their amalgams, zinc, tin, lead, copper, iron, silver, palladium, gold, platinum, &c.

With the Solutions of Hydro-Sulphurets.

Arrangements consisting of one Conductor and two Imperfect Conductors.

Solution of sulphur and potash of potash . . . . of soda	Copper. Silver. Lead. Tin. Zinc. Other metals. Charcoal.	Nitric acid. Sulphuric acid. Muriatic acid. Any solution containing acid.

The most splendid effects of the voltaic battery achieved by Sir H. Davy were the decomposition of the alkalies and alkaline earths, as potash, soda, baryta, strontia, lime, and magnesia. These were found to be composed of a brilliant

white metal combined with oxygen, which were separated and exhibited at the opposite poles of the battery. This mode of decomposition, arising from electric repulsion, has afforded a convenient basis for the arrangement of the simple substances for the convenience of study, and by its means they are divided into two classes. The first consists of those elements which are attracted from their compounds with substances of the other class, by the positive pole of the voltaic pile; and as bodies in opposite states of electricity attract one another, they have been called *electro-negative* bodies. The second comprises those elements that are attracted by the negative pole, which are therefore termed *electro-positive* bodies. Before giving a list of the simple substances, it will be necessary to allude to the theory of equivalents. In an early part of this article we have stated that different bodies combine in proportions that are fixed with regard to each other in a given compound. We may now observe that these proportions are definite with regard to every other substance with which they are capable of entering into composition, so that there are certain determinate proportions of all bodies which are equivalent to each other in their powers of combining with all other bodies. Thus, acetate of lead is a compound of 50 parts of acetic acid and 112 parts of lead, in the state of an oxide. White vitriol, or sulphate of zinc, is composed of 40 parts of sulphuric acid and 41 parts of oxide of zinc. Now these proportions are all equivalent to one another, and if the numbers are written against the different substances as follows, we can at once perceive the proportions in which they will unite in any new combination.

Sulphuric acid	40
Zinc (oxide)	41
Acetic acid	50
Lead (oxide)	112

The same equivalent numbers or their multiples are preserved in every possible combination with other bodies; and when any body is compounded of two simple substances, the sum of the equivalents of the two elements will give the number, denoting the proportion in which it will combine. Thus the prime equivalent of hydrogen is 1, that of oxygen 8; these combine to form water, the equivalent of which is 9. The following table contains the names of those substances which being, in the present state of chemistry, undecomposable, are considered as simple elementary bodies, classed in two divisions, and having their equivalent or combining numbers attached.

Non-Metallic.

	Electro-negative.	Equivalents.	Electro-positive.	Equivalents.
Aëriform.	Oxygen	8	Hydrogen	1
	Chlorine	36	Nitrogen	14
Volatile.	Bromine	75		
	Iodine	124		
	. . . .		Sulphur	16
	. . . .		Phosphorus	12
	. . . .		Selenium	40
Fixed.	. . . .		Carbon	6
	. . . .		Silicon	8
	. . . .		Boron	6

Metallic Elements.

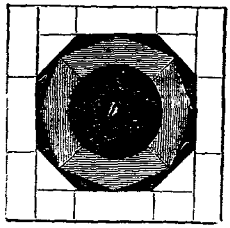
	Electro-negative.	Equivalents.	Electro-positive.	Equivalents
Oxides reducible by mere heat, (*noble metals*).	. . . .		Mercury . .	200
	. . . .		Silver . . .	110
	. . . .		Gold . . .	200
	. . . .		Platinum . .	96
	. . . .		Palladium . .	56
	. . . .		Rhodium . .	44
	. . . .		Iridium . .	?
	. . . .		Osmium . .	?
	. . . .		Nickel . . .	30
Do not decompose water at any temperature.	. . . .		Lead . . .	104
	. . . .		Tellurium . .	29
	. . . .		Copper . .	64
	. . . .		Bismuth . .	71
	. . . .		Titanium . .	?
	. . . .		Cobalt . . .	?
	. . . .		Cerium . .	?
	. . . .		Uranium . .	?
	. . . .		Antimony . .	44
	. . . .		Columbium .	144
	. . . .		Tungsten . .	96
	. . . .		Chromium .	28
	. . . .		Molybdenum .	48
	. . . .		Arsenic . .	38
Decompose water at a red heat.	. . . .		Tin	59
	. . . .		Iron . . .	28
	. . . .		Zinc . . .	34
	. . . .		Cadmium . .	56
	. . . .		Manganese .	28
Decompose water at atmospheric temperatures. Oxides, caustic, (*alkaline metals.*)	. . . .		Potassium . .	40
	. . . .		Sodium . .	24
	. . . .		Lithium . .	10
	. . . .		Calcium . .	20
	. . . .		Barium . .	70
	. . . .		Strontium . .	44
Decompose water below a red heat, but oxides insipid. (*Earthy metals*).	. . . .		Magnesium .	12
	. . . .		Glucinum . .	20
	. . . .		Yttrium . .	34
	. . . .		Aluminum .	10
	. . . .		Zirconium .	?

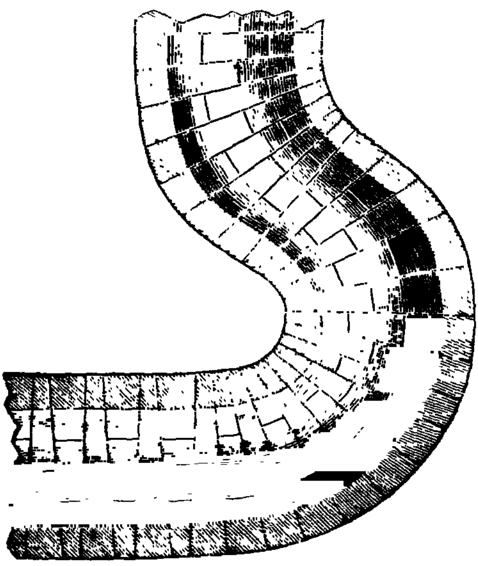
A particular description of the properties of these bodies, with the compounds formed by their union with each other, will be found under the initial letter of their respective names.

CHIMES. A piece of musical mechanism produced at equal intervals of time by the strokes of a hammer against a series of bells. This is effected by means of a chime-barrel, which is something of the nature of a barrel to an organ. It is a cylinder of brass in small clocks, or of wood in church clocks, which gives motion to the hammers that strike the bells, and produce a change or tune by means of pegs inserted into certain points of its circumference at measured intervals.

CHIMNEY. An aperture or passage for the escape of the smoke and heated air from a furnace or fire-place, and for producing a more perfect combustion by determining a rapid current of air through the fuel. The principle upon which the action of a chimney depends, is, that the air in the chimney

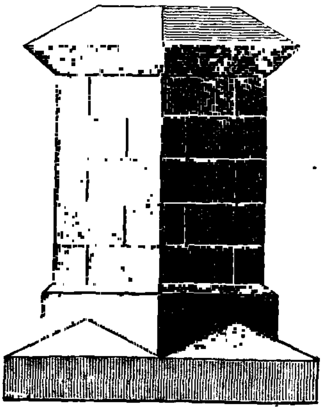
becoming rarefied, its specific gravity is diminished, and the weight of the column of air within the chimney becoming less than the weight of a column of the external air of the same altitude, the heated air in consequence escapes at the top of the chimney, and is replaced by the colder and denser air, which enters at the bottom. The greater, therefore, the height of the chimney, the greater will be the effect; for the greater will be the difference in the weight of the two columns of air. In Mr. Tredgold's work on warming and ventilating apartments, the following rule is given for the orifices of chimneys according to the height and magnitude of the fire-places. Multiply by 17 the length of the fire-place in inches, and divide by the square root of the height of the chimney (above the grate) in feet, and the quotient is the area in inches for the aperture of the chimney. Mr. Hiort, of the Office of Works, Whitehall, has taken out a patent for a new method of building chimney flues and tunnels, which has been adopted in the new palace, Pimlico, and in several public buildings, and has given great satisfaction. The plan consists in building within the usual walls, and incorporated with the common brick-work, circular smoke flues or tunnels, as seen in the annexed plan or horizontal section at *b*. Each flue or tunnel is surrounded in every direction, from top to bottom, by cavities or hot-air chambers *c c*, commencing at the back of each fire-place, and connected with each other. The air confined within these chambers is said to be rendered sufficiently warm by the heat of any one fire, to prevent condensation in all the flues contained in the same stack of chimneys. The figure of each brick composing these circular flues is wedge-like, or inclined, as respects its upper and lower surfaces: the external face is composed of two planes, forming a very obtuse angle with each other; and the internal, of the arc of a circle, to the centre of which the two ends of the brick tend or radiate; and the whole circle is completed by placing four bricks together, end to end, as shown in the fore-





going plan. Their inclined figure is best shown in the engraving above, from which it will likewise be seen that the flues or tunnels may be carried in any

direction without producing any internal angles, the bricks being readily adapted to any required curvature. To make the flue straight, it will be observed that the thick ends of one course of bricks are placed alternately upon the thin ends of the next course; and in order to make curves, the thick ends are placed together on one side, and the thin ends on the opposite side. The circular flue commences at the throat of the chimney below the usual line of the chimney bar, and immediately over the fire. From below the chimney-bar the flue is continued



downward to the hearth in a half-circle, forming the centre of the back of the fire-place. From the construction of these chimneys, and the nature of the materials of which they consist, no danger need be apprehended should the soot ignite (an accident not likely to happen), for such an accumulation of soot as common chimneys are liable to cannot take place within these flues, there being no angles within which it can lodge, the draught of air being much stronger through them, and the necessity for cleansing them may be rendered less frequent by vitrifying the inside of the bricks to prevent adhesion; nevertheless, the operation of cleansing may with facility be performed without the aid of climbing boys, all sharp angular turns, and other impediments which have hitherto opposed the use of machinery for this purpose being totally avoided.

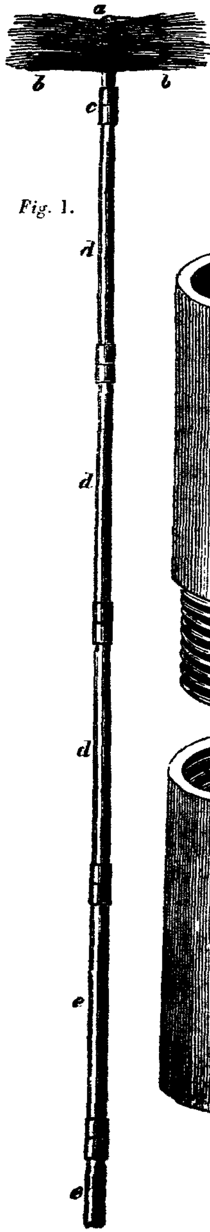


Fig. 1.

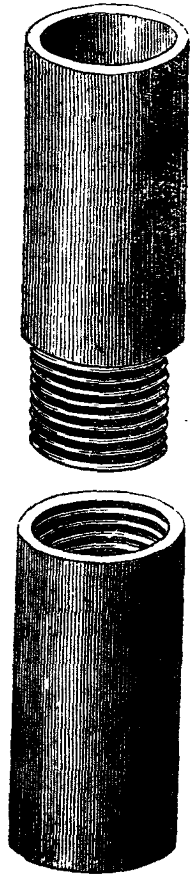


Fig. 2.

Whilst upon this subject, we have great pleasure in calling the attention of our readers to a very effective machine for sweeping chimneys, invented by Mr. Glass, which has been approved by the Society for Superseding the

Necessity of Climbing Boys, and which seems applicable to almost every construction of flues. The brush, *Fig.* 1, is made of a round stock *a*, commonly alder, and pierced with small holes, into which bunches, formed of strips of the best whalebone, are inserted and fastened by glue. These strips *b* are from 8 to 8½ inches in length, which renders the brush, including the stock, about 20 inches in diameter; it therefore completely fills, and effectually cleanses, the largest flues, which are never more than 14 inches square, and are seldom more than 14 by 9 inches. At the end of the stock *c* is a very strong brass ferrule, with a wormed socket, which receives the screw of the first joint. *Fig.* 2 is a representation of the ferrules of the real size; the three first portions *d d d*, 2½ feet in length, are made of good cane, the rest *e e e* of ground ash, and of the same length, the number used of course depending upon the height of the chimney; these are made gradually stronger towards the bottom, and are affixed to each other by means of the brass screws and sockets in *Fig.* 2, before described. The superiority of this machine consists in extreme pliability, lightness, and strength, which render it peculiarly applicable in high chimneys having a diagonal portion at *b*, as shown in the annexed *Fig.* 3. If Glass's machine be introduced through B, it will proceed to the top of A with ease, whilst most other machines generally stick at *b*. A common defect in the construction of chimneys, although not so great in houses of recent construction, is, that the aperture is generally much larger than necessary for the passage of the smoke, the consequence of which is, that the fuel in the grate not being sufficient to rarefy the whole portion of the air in the flue, the rising current of heated air is met by a descending current of cold air, and the smoke is borne back into the room. By Mr. Tredgold's rule, before given, it appears, for a grate 18 inches wide, a chimney 36 feet in height would require an aperture of only 51 inches area, little more than 7 inches square, whereas no chimneys are less than 14 inches by 9. It is true that they could not be swept by climbing boys if made of less dimensions; but if carried up in nearly a straight direction, without abrupt bends, they might be easily cleaned by machinery, by which means a barbarous and inhuman practice would be abolished, and the proper dimensions being assigned to the chimney, the annoyance of smoke in the apartments would be got rid of. The most effectual remedy for smoky chimneys is to

Fig. 3.

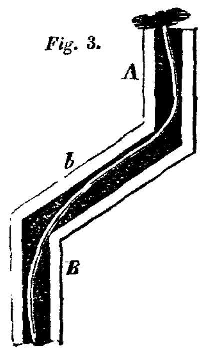


Fig. 1.

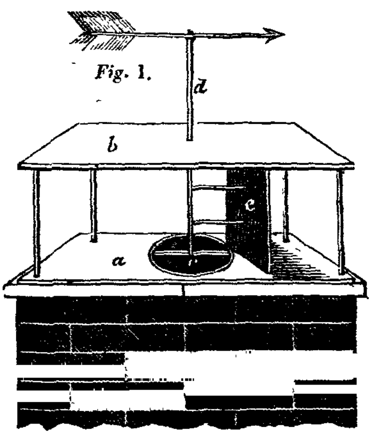
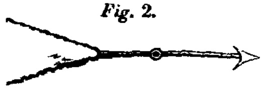
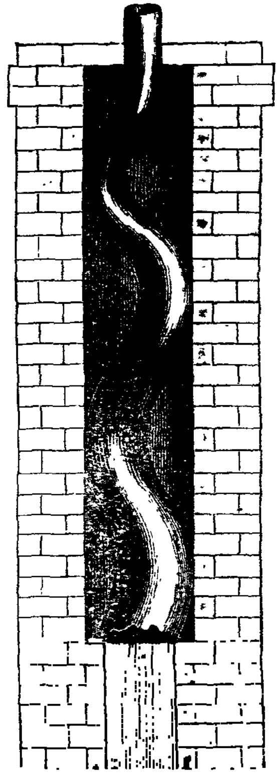


Fig. 2.



contract the aperture, and lower the breast of the chimney; and when this has been carried as far as is practicable, some further benefit may be derived by

placing on the summit a revolving cap, turned by a vane, so that the aperture for the smoke shall always be to leeward. A machine of this description, invented by Capt. Halliday, is represented in the engraving on the preceding page. *a* and *b* are two square plates of iron, or other metal, the upper one being supported by four vertical pillars; *c* is the aperture for the passage of the smoke from the brick flue immediately beneath; across this aperture a bar is fixed horizontally, supporting the upright spindle *d*, on the upper end of which is fixed a double-tailed vane, shown in plan at *Fig.* 2. Below the plate *b* a square plate, forming a screen or guard, is attached by braces to the spindle, and the spindle being turned by the action of the wind upon the vane, the screen is constantly opposed directly to the wind.



The sketch below exhibits a smoke cowl commonly used at Glasgow:—*Fig.* 1 is an elevation, and *Fig.* 2 a plan or horizontal section of the contrivance, which consists of a quadrangular box of sheet iron, surmounted by a pyramidical cap, and placed, as exhibited, over the top of the brick flue. There are four doors to it, *a b c d; a* is connected by an intermediate rod *f* to the opposite door *c*, and *b*, by the rod *e* to the door *d*, so that when the wind closes the door opposed to it, the opposite one is opened for the smoke to escape uninfluenced by the wind.

The annexed engraving represents Mr. Fenner's apparatus for curing smoky chimneys. It consists of a spiral tube or flue to the upper part of an ordinary chimney. These tubes are made of thin copper, and furnished with

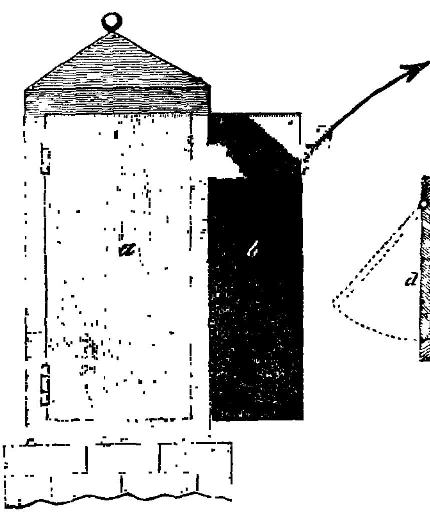
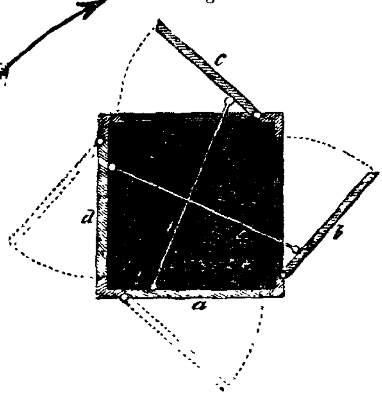


Fig. 2.



a flange at the lowest end upon which it rests on the top of the brick-work of the ordinary flue. The chimney is then continued upwards with a reduced thickness of brick-work, by which means the capacity is sufficiently enlarged for the reception of the spiral tube. The expanded part of the chimney is closed in at top so as to form a hot-air chamber round the tube, which being of thin metal, the heat is readily transmitted to the chamber.

CHLORINE. The name given by Sir Humphrey Davy to a gas which long went, and even still commonly goes, by the name of oxymuriatic acid gas, as being imagined to be a compound of oxygen and muriatic acid, but which he showed to be a simple substance, which, when combined with hydrogen, formed muriatic acid. Chlorine is commonly, in the small way, obtained by distilling in a glass retort, at a gentle heat, 3 parts of common salt, 1 part of black oxide of manganese, and 2 parts of sulphuric acid. The gas which comes over is of a greenish yellow colour, and its odour and taste are disagreeable, strong, and so characteristic, that it is impossible to mistake it for any other gas. Like oxygen, it is a supporter of combustion, the products of which are termed chlorides. It has two remarkable properties: 1st, Its affinity for hydrogen is superior to that of any other substance, whence it is extremely useful in destroying contagious miasmata; and 2dly, its destructive action upon vegetable colours, with the aid of a little moisture. Scheele first remarked this property, Berthollett applied it to the art of bleaching in France, and Mr. Watt introduced its use into Great Britain. The alkaline metals, as well as copper, tin, arsenic, zinc, antimony, in fine laminæ or filings, spontaneously burn in chlorine: metallic chlorides result. Phosphorus also takes fire at ordinary temperatures, and is converted into a chloride. Sulphur may be melted in the gas without taking fire. See BLEACHING.

CHOCOLATE. A kind of paste or cake prepared from several ingredients, the chief and basis of which is the cacao nut. The cacao, after being roasted, is ground to a paste. The English manufacturers are said to mix the flour of horse-beans, or other farinaceous vegetable matter, to soften the strong taste of the cacao; some vanilla and sugar are likewise added by them. The Spanish chocolate contains cloves, cinnamon, besides musk, ambergris, &c., which are not agreeable to the English palate.

Fig. 1.

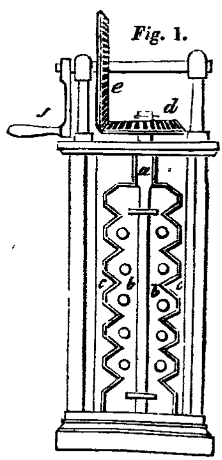
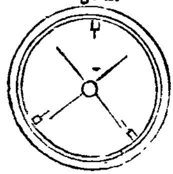


Fig. 2.



CHURN. A vessel in which butter is obtained from milk or cream by agitation. A great variety of churns are in use; a very common one consists of a deep wooden tub, rather conical, resting on its base, and having a wooden cover, through which passes the churn staff, to the bottom of which is fixed a broad kind of foot, having numerous perforations to occasion a more universal agitation of the milk in churning, the staff being worked briskly up and down. From the mode in which the power is applied in this kind of churn, the operation is very laborious; another kind, therefore, called the barrel churn, is now very generally adopted in our dairies, which consists of a kind of rolling barrel with an apparatus within it, calculated to quicken the formation of the butter by promoting the agitation of the milk. The annexed engraving represents an elegant little table churn, constructed of glass by Messrs. Pellat and Green, which shows the manner in which butter is formed in a very interesting manner. *a* represents an axis placed vertically in a glass cylinder, and furnished with four leaves *b b*, placed at right angles to each other, (as seen in *Fig.* 2,) and notched on the edges, and also perforated (as shown in *Fig.* 1). To the interior of

the cylinder are fixed three leaves *c c*, at equal distances from each other, and also notched on the edges so as to receive the projecting points of the leaves attached to the axis, and nearly fit them, at the same time allowing the movable leaves to pass freely when the axis is turned round. The agitation is produced by a rapid rotation of the axis with its leaves or fans, which is effected by means of the bevilled wheel *d* and *e*, put in motion by the handle *f*.

CINCHONA is the bark of several species of cinchona, which grow in South America; of this bark there are several varieties, the red, the yellow, and the pale. The red is in large easily pulverized pieces, which furnish a reddish brown powder, having a bitter astringent taste. The *yellow Peruvian* bark was first brought to this country about the year 1790, and it resembles pretty closely in composition the red species. The pale cinchona is that generally employed in medical practice as a tonic and febrifuge.

CINNABAR. A beautiful red pigment, composed of sulphur and mercury, and hence in the chemical nomenclature called sulphuret of mercury.

CINNAMON. The inner bark of the *laurus cinnamonum*, a native of Ceylon. It is a most grateful aromatic, of a very fragrant smell, and a moderately pungent taste, and is an excellent restorative spice.

CIRCLE. A line continued till it ends where it began, having all its parts equidistant from a common centre.

CIRCUMFERENCE. The periphery or line bounding or including any thing.

CIRCUMFERENTOR. A mathematical instrument used by surveyors for taking angles by the magnetic needle in cases where great accuracy is not required, and where a permanent direction of the needle is of the most material consequence in surveying. It consists of a compass box containing a magnetic needle, supported on a pivot in the centre, and the circumference of the box divided into 360 parts or degrees. The box is furnished with two sights, placed on opposite ends of the meridian line, or 180° asunder; it is also mounted on a pivot in the head of a tripod or stand. In taking the angle between two objects with this instrument, the box is turned until one object is seen through the sights, when the number of degrees to which the south end of the needle points is noted; the box is then turned until the second object be observed through the sights, and the degrees pointed to by the needle again noted, and the difference between the two numbers is the quantity of the angle.

CITRIC ACID. An acid obtained from the juice of lemons, although it is also contained in various other fruits and vegetables. The usual method of preparing it consists in saturating a quantity of the juice of lemons by chalk, which thus forms citrate of lime, and afterwards decomposing the citrate by diluted sulphuric acid, by which means sulphate of lime is formed, and the citric acid is set free, and in this state it is used by the calico printers; but for other purposes it is crystallized by evaporation. There is an interesting paper on this subject in *Parkes's Chemical Essays*.

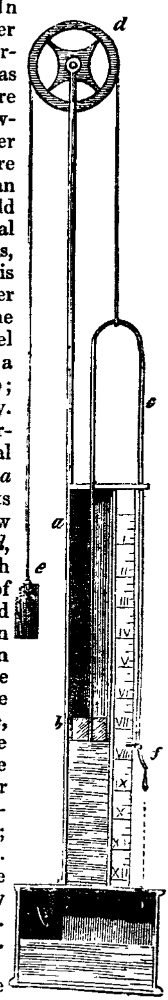
CIVET. A perfume which bears the name of the animal from whence it is taken, called a civet cat (found in China and the East and West Indies), but bearing a greater resemblance to a fox or marten than a cat. Several of these animals have been brought into Holland, and afford a considerable branch of commerce, particularly at Amsterdam. The civet is collected near the anus of this fierce carnivorous quadruped, and squeezed out in summer every other day, in winter twice a week; the quantity procured at once is from two scruples to a drachm or more. The juice thus collected is much purer and finer than that which the animal sheds against shrubs or stones in its native climates. Good civet is of a clear yellowish or brownish colour, not fluid nor hard, but about the consistence of butter or honey, and uniform throughout; of a very strong smell, quite offensive when undiluted, but agreeable when only a small portion is mixed with other substances.

CLARIFICATION. The process of clearing or fining any fluid from heterogeneous matter or feculence by chemical means, thus differing from filtration, which is merely a mechanical operation. Clarification is performed

either by heat, or by the addition of some substance which will unite with, and either precipitate to the bottom, or carry to the surface, the matter which renders the liquid turbid.

CLARINET. A wind instrument of the reed kind.

CLEPSYDRA, or WATER CLOCK. A contrivance of very great antiquity, to measure the lapse of time, and indicate the hour by the flowing of water into or out of a vessel properly graduated. In the former case the vessel was divided by lines into a number of equal parts, which would be filled with water in equal portions of time provided the source from whence the water was obtained was so abundant as to render the hydrostatic pressure upon the discharging aperture nearly equal. Such clocks, however, could be employed in particular situations only, the latter plan was therefore most commonly adopted, viz. to measure by the discharge of water *from* the vessel; but as in this plan the velocity of the water would not be uniform, but would decrease with the decrease of the water in the vessel, equal quantities of water would not be discharged in equal times, and some contrivance became necessary to compensate this inequality. The most common was to employ a vessel of larger diameter at the upper than at the lower end, and divide the altitude into a number of equal parts, or else to use a vessel of equal diameter throughout, and divide the height into a number of unequal parts, gradually diminishing from the top; but each of these methods was difficult to execute accurately. The cut in the margin represents a contrivance of Mr. Partington's, by which these difficulties are avoided, and equal quantities of water are discharged in equal spaces of time. *a* is a cylindrical tube to hold the water, and *b* a cork float on its surface, through which is passed the shortest leg of a narrow syphon *c*, which is suspended by a silken cord over a wheel *d*, and to the other end of the cord is attached a weight, which nearly counterbalances the syphon; near to the extremity of the syphon is fixed an index *f*, that points out upon a graduated scale the hour, according to the degree of depression within the tube. It is obvious that as the float by which the syphon is supported is always immersed to the same depth in the water, the outer leg of the syphon will always remain in the same relative position to the surface of the water in the tube, and thus the hydrostatic pressure will be always the same, the flow or discharge will be uniform, or equal portions will be discharged in equal times, and the tube being cylindrical, or of the same dimension throughout its length, the scale corresponding to its altitude will be divided into equal parts; thus the instrument forms a very accurate measurer of time. The water falls into a receiver *g*, which forms the base of the instrument, and may be made to run back into the tube by opening a passage between them, and inclining the instrument.



CLOCK. An instrument for measuring and indicating time. See HOROLOGY.

CLOG. In the manege, a log of wood fastened to the fetlocks of a horse, to break him in to a peculiar kind of pace or step.

CLOG. A sort of shoe with a thick sole of wood or leather, worn over the ordinary boots and shoes in dirty weather. Although clogs are more easy to walk in than pattens, as affording a firmer footing, they are not so cleanly, as they splash and throw up a deal of dirt. The figures on the opposite page represent a combination of the clog and the patten, affording the security and firmness of the tread of the former, and the cleanliness of the latter. *Fig.* 1 shows the patten clog in perspective, and *Fig.* 2 the same turned upside down. *a* is the patten

iron, of the peculiar form represented, which is found not to splash in the least; it is rivetted to the bottom of the clog, as a support to the heel, and is upon a level with the projecting or thickest parts *b* of the sole that supports the fore part of the foot. The clog is hollowed out at *c* to render it lighter, and to cause it to take up less dirt. One objection to clogs, as usually constructed, is the

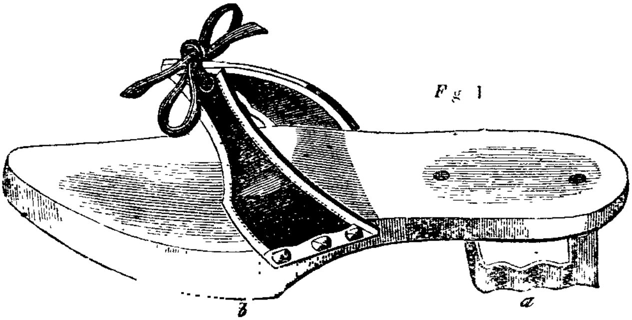
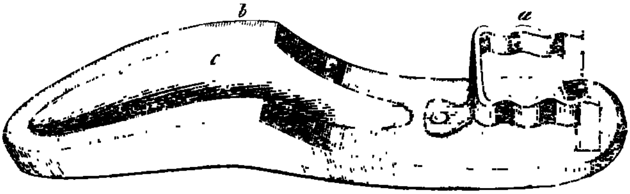


Fig. 1

Fig. 2.



fatigue they occasion in walking, from their want of flexibility. This defect has of late years been remedied by forming the sole of two or more pieces, connected by hinges; and a further improvement has been introduced by Mr. Schaller, who has obtained a patent for what he terms "expanding clogs or pattens," which may be lengthened or contracted at pleasure, so as to fit the foot of the wearer with the greatest exactness. These expanding clogs are represented in the engravings on page 372. *Fig.* 1 represents a man's clog in perspective, with the contrivance for expanding or contracting the same. Under the brass ferule at *a* is a sliding rack and spring, or other contrivance, by which the clog can be lengthened or shortened at pleasure; at *b* is another rack and spring, which allows the raised sides of the heel-piece to be expanded or contracted breadthwise. To the strap *c* is likewise attached an improved spring slide, by which that also may be lengthened or shortened: these several contrivances are exhibited in detail in *Figs.* 2, 3, 4, 5, 6. *Fig.* 3 represents a plan of the upper side of the sole of the clogs, without the brass ferule or sheath *a*, and with another flat plate, which encloses the work underneath, removed; the rack *d* and the spring *e* are thus brought into view, the former being screwed to the waist of the sole, and the latter to the heel piece, in cavities or mortises made to receive them; they are likewise so fixed that the spring always keeps in contact with the rack, as shown by the edge view of them in *Fig.* 4, where it is seen that there is a stout pin *f* which goes through a slot mortise in the rack: this pin slides backwards and forwards in the slot mortise. By this arrangement it will be seen that the clog may be contracted by simply thrusting the toe part towards the heel, as the spring catch, which is fastened to the former, slides over the notches in the rack; but to pull the toe from the heel, in order to lengthen the clog, it becomes necessary to press upon the brass pin *f*, which in this clog protrudes a little way either on the upper or the under side. *Fig.* 2

represents a plan of the upper sole of the superadded heel-piece, which consists of a metal plate *g*. The sides *h h* are here shown as expanded for a large foot; to contract it to suit a smaller foot it is only necessary to press the sides *h h* together, when a spring catch (nearly similar to that already described in the other part of the clog) slides over the notches of a rack, and fixes itself wherever

Fig. 1.

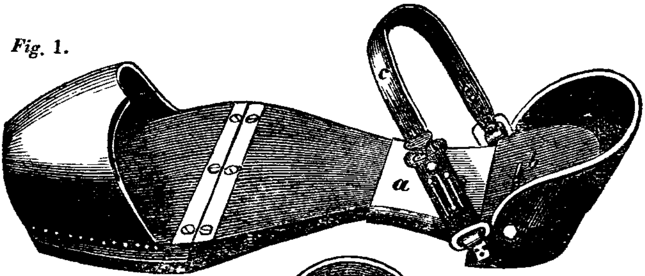


Fig. 2.

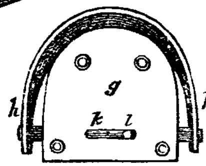


Fig. 3.

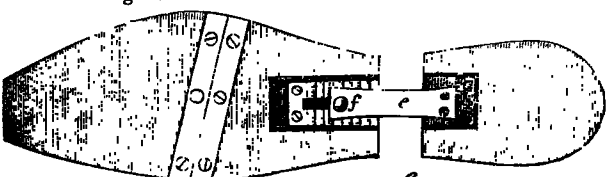


Fig. 4.

Fig. 5.

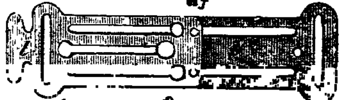
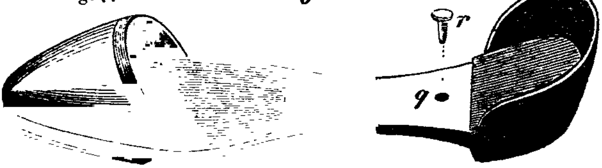


Fig. 6.

Fig. 7.



it is left. On the contrary, when it is wished to increase the capacity of the heel, the guide pin *i* which slides in the slot mortise *k* is to be pressed upon by the thumb nail, which thrusts the spring catch out of contact with the rack, and the sides *h h* spring out again in the position shown in the figure, owing to their having a metallic lining (of thin plate iron), which possesses sufficient elasticity for that purpose; the four screw holes, shown in the heel-plate *g*, are for the purpose of fastening it down to the wood or leather heel-piece of the clog. The slide for lengthening or shortening the tie of the clog across the instep of the wearer is shown on an enlarged scale at *Figs.* 5 and 6, the same

letters in each referring to the same parts. It consists of two plates *l l* laid flat-wise in contact with each other, with four long apertures or slots, in each of which slides a brass pin; two of these pins are rivetted to each plate, and confine the opposite plate in contact by their heads projecting over it. To give an increased friction to the sliding plates, and to stop their action, a spring *n* is fixed to one of the plates, with a brass catch pin *o* at the other end, so that when the slide is shut up, as shown in *Fig.* 1, the pin *o* enters the hole *p*, where it is retained, until pressed out again in order to lengthen the tie as may be required. *Fig.* 7 represents a clog more especially adapted to ladies' wear, in which another mode of lengthening or shortening the clog is adopted. In this instance a thin iron bar or plate is perforated with holes and rivetted to the fore part of the sole, and kept steady by two pins on either side; the other end of the perforated plate enters the heel of the clog, and is so formed at the extremity as to prevent it being entirely drawn out. Now the brass sheath *a* has a hole at *q*, and another directly opposite to it at the bottom; the pin *r* being then passed through both holes in the brass sheath, and through one of the holes in the intervening perforated plate, fixes the clog firmly in the place required.

CLOTH. A general name for any fabric woven from any fibrous materials (except silk), such as flax, cotton, &c., but it is mostly used to signify cloth made from wool. See WEAVING and WOOLLEN MANUFACTURE.

CLOUTS. Thin plates of iron, which are nailed to the wooden axletrees of carriages.

CLOVES. The produce of the caryophillus aromaticus of Linnæus, which grows in the Molucca Islands, particularly in Amboyna, where it is principally cultivated. The clove tree resembles in its bark the olive, and is about the height of the laurel, which it also resembles in its leaves. No verdure is ever seen under it. It has a great number of branches, at the extremities of which are produced vast quantities of flowers, that are first white, then green, and at last red and hard. When they arrive at this degree of maturity, they are, properly speaking, cloves. The season for gathering is from October to February, when the boughs of the trees are shaken, or the cloves beaten down by reeds, large cloths being spread to receive them. These are afterwards either dried in the sun, or in the smoke of the bamboo cane.

CLUTCH. A mode of connecting shafts with each other or with wheels, so as to be disengaged at pleasure; numerous examples of which have been given in the preceding part of this work. See also MILLWORK.

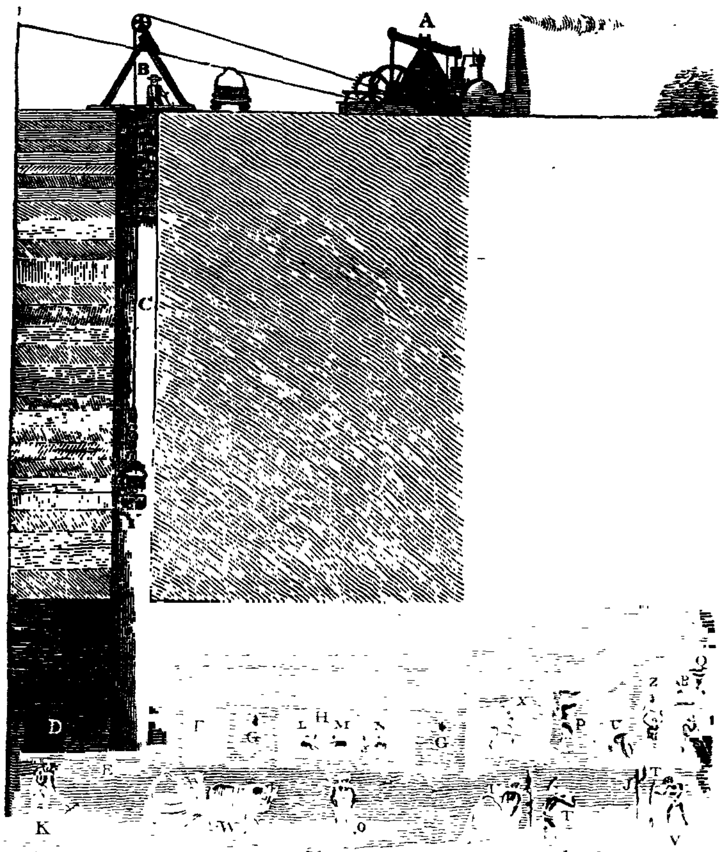
COAL. A carbonaceous substance lying in strata at various depths beneath the surface of the earth, and extensively used for fuel. The varieties of coal are scientifically described by Dr. Jamieson in his geological work, and classed in several species and subspecies; but, in a practical point of view, they may be divided into three classes, according to their degree of inflammability. The least inflammable kind is the *anthracite*, or *stone coal*, of which class is the Welsh and Kilkenny coal. It requires a considerable degree of heat to ignite it, but when once kindled it remains in distinct pieces in the fire without caking, producing neither smoke nor flame, making no cinder, but leaving a stony slag behind. It is chiefly used in malt kilns, dye-houses, &c. *Open burning coal* kindles quickly, makes a hot pleasant fire, but is soon consumed, and produces smoke and flame in abundance; it lies open in the fire, and does not cake together to form cinders, its surface being burnt to ashes before it is thoroughly calcined in the middle. Of this kind is Cannel coal, jet, and most of the Staffordshire and Scotch coals. *Close burning coal* kindles quickly, makes a very hot fire, melts and runs together like bitumen; it makes a more durable fire than any other kind of coal, and burns finally to ashes of a brownish colour. Of this kind are the Newcastle coals, and those of the surrounding districts. The various kinds of coal are often found mixed with each other, and at times some of the finer sorts run like veins between the coarser sorts.

COAL MINE. Strata of coal are to be met with in various parts of the globe, as France, Germany, Sweden, America, Australia, and we believe likewise in India; but in no country in such profusion, or of so good a quality, as in Great Britain; and to this circumstance we may mainly attribute our commercial

greatness, and our superiority in almost every branch of manufacture. In coal mining, and the carrying trade, a vast portion of our population is employed, besides many hundreds of thousands of tons of shipping constantly engaged in transporting this valuable mineral not only to all parts of our own coasts, and up our rivers, but to almost every part of the Netherlands, France, Spain, Portugal, the West Indies, and America. The principal seat of the coal trade is in the northern and eastern parts of England, and the most important coal works are those of Newcastle and Whitehaven; at the latter place some of the mines extend more than a mile under the sea, and at a depth considerably greater below its surface than has been reached in any part of the world, the deep mines of South America being situated upon lofty mountains considerably elevated above the surface of the earth.

We shall now proceed to give a brief description of the method of working a coal mine. To ascertain whether coal is concealed beneath the surface at any place, recourse is had to boring, by a process and implements similar to what we have already described in our account of the method of boring for water; and an account is carefully kept of the different strata cut through, and of the depths to which they extend before arriving at the principal bed of coal; and the thickness of the coal strata in different situations, as well as the dip or inclination of the strata, (for they seldom lie horizontal,) are ascertained by the same means. The working is usually commenced upon the *dip*, as it is termed, or where the depression of the strata of coal is greatest. The first consideration is the means of draining off the water from the feeders and springs with which the coal is usually intersected. If the situation and other circumstances will admit of it, an adit is driven through the side of the hill to the lowest part of the mine, and the water runs off by it to a lower level; but if this cannot be effected, the water is raised by pumps worked by horses, water, or steam, according to circumstances. For this purpose a pit or shaft, termed the "engine shaft," is sunk (generally upon the dip of the coal), in order to allow the water to drain from the workings and to keep them dry. In this shaft the pumps are placed, divided into sets at the various depths of the mine, the lowest set delivering its water into a cistern, from which it is raised by the next set of pumps above it, and so on to the surface, the lift for each set seldom exceeding 25 to 30 fathoms. When the required depth is attained, a portion of coal is worked dipward of the engine-shaft, forming a cistern for the waters to collect in. A level is then cut, from the bottom of the engine-shaft, called the gateway, or winning headway, which, as the works proceed, is carried the whole length of the mine, and is from 8 to 10 feet high, and 9 feet wide. When the gateway has proceeded to the required distance from the engine shaft, another shaft is sunk to meet it, called the coal shaft, or pit, by which the coals are conveyed to the surface in baskets by a gin. From the gateway, or winning headway, the coal is worked from passages cut at right angles, called "rooms," which are about 12 feet wide; and other passages again are cut at right angles to the rooms, which open from one room into the next, and are called "thoroughs," or thirtings, the coal remaining thus forming pillars for the support of the roof. When the coal is of a firm texture, from two-thirds to three-fourths may be got out at the first working; but in other cases little more than a half. Two large blocks or pillars, 15 or 20 yards long by 10 or 15 yards wide, are left to protect engine and coal-pit, in case of the falling in of the mine. The coals are brought to the pit or shaft in small cars, drawn by horses when the workings are wide and moderately level; but if too steep or narrow, are drawn by men in baskets upon trucks; or if too steep for this, are carried in baskets upon the backs of women. A general idea of the operations and arrangements of a coal-mine may be gathered from the accompanying section of Bradley Coal Mine, near Bilston, in Staffordshire. A, the whimsey, or steam-engine for raising the coal from the bottom of the shaft; B, the banksman who lands the same; C, one of the shafts of the mine; D, a passage from one shaft to another; E, the gateway, or head-winning way; F, the bolt hole, made to cause a free circulation of air through the mine; (should any part take fire, the bolt hole is built up;) G, pillars left in working the ten-yard coal, to support the superjacent strata;

H, an excavation called a stall, or room, by the colliers, who, after the gateway is cut, begin thus to work the coal, or hole-under; I, the ribs through which the air-way is cut; J, lights; K, a man who hangs on the skips, and rakes the gateway; L M N, miners heading, holing, and shovelling out the slack or small coal; O, slack carrier; P, miner working on a scaffold; Q, the spern, a small piece of coal left as a support to many tons above, which fall when this is taken away; R, a collier on a scaffold, taking out the spern as far as he can reach with a pick; S, a collier standing upon a heap of slack, called the gob, with a prong used for that work, which cannot be safely done with a pick; T,

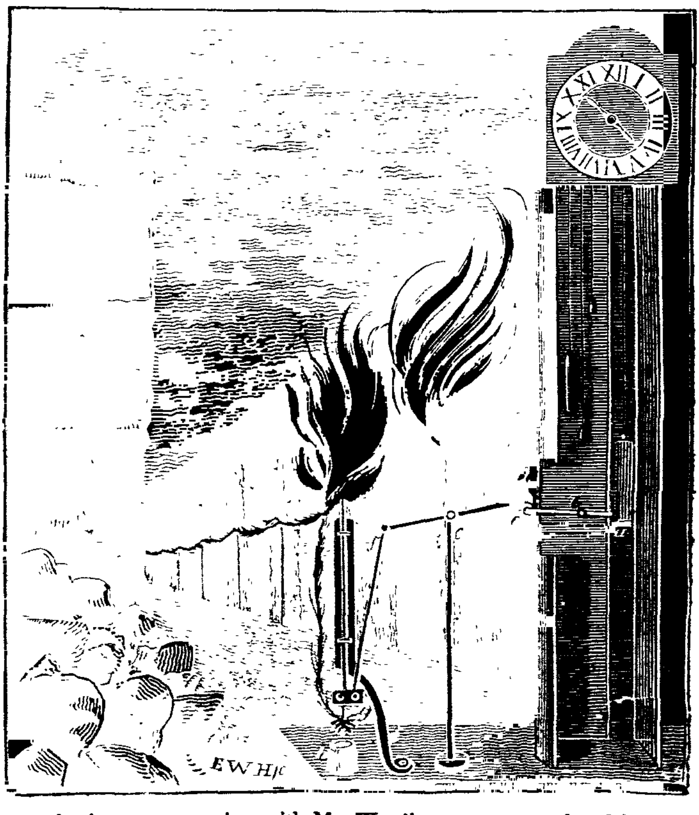


a collier breaking or turning out coal; U, a collier loading a skip; V, a collier breaking the large coal with a wedge; W, a driver with an empty skip, X, a driver with a loaded skip; Y, a skip being drawn up the shaft by the engine; Z, a pillar, called the man of war, left to support the upper strata until the lower are worked; it is then taken away, and the upper coal falls down. The different strata that are cut through to arrive at the principal bed of the coal are exhibited on the left of the shaft, by variously shaded portions of the solid earth, extending in the Bradley mine to the depth of about 111 feet,—the depth to the bottom of the shaft is 139 feet 4 inches. In the extensive collieries in the vicinity of Newcastle a complicated and

expensive system of ventilation has been adopted, in order to guard against the disastrous consequences which result from an accumulation of fire-damp or hydrogen gas; but from the calamitous explosions, which are of such frequent occurrence, it is but too clear that the system is deplorably inefficient, and calls loudly for improvement. The accompanying sketch represents, on a small

scale, the plan which is pursued to counteract the effects of that fatal evil, and to spread throughout the workings a sufficient quantity of fresh air. The dark parts in the plan represent the pillars of coal left to support the roof, and the light parts the workings. There are generally two descents or more to the mine, as we have already stated, which are distinguished by the terms of the downcast and upcast shaft. A is the downcast shaft by which the air descends; the current of the air is represented by the waved line, which is carried through the main passages only, the subways which diverge from them being stopped by the brattices; and its motion is accelerated by the heat of a large furnace, situated at the bottom of the upcast shaft B; and thus the air, after traversing the whole of the workings, ascends the shaft B. An exhausting pump placed near the upper end of the upcast shaft B is sometimes substituted for the dangerous expedient of the furnace at the bottom of the shaft. But when particular parts of the mine are subject to rapid accumulations of fire-damp, recourse is had to the firing process, which is usually performed by means of an apparatus, consisting of a long pole, or a series of poles, fitting one into another like a fishing-rod, so as to be elevated to the break, or *pot-hole*, where the fire-damp has accumulated; at the upper end of this pole is a small sheeve or wheel, over which a copper wire passes, of sufficient length to reach to the horse stable from any part of the mine; this done, the pole is firmly fixed in the place where the gas lodges. A candle, fixed to a piece of lead or other substance to keep it upright when suspended, is carried by the fireman as far towards the explosive region as safety will admit, when it is set upon the floor, and fastened to one end of the copper wire, after which the firemen retire to the stable, which is made strong and well secured, in order to barricade them: the other end of the wire is brought through a crevice in the door, and by this means the light is drawn up to its destination; and the gas which has accumulated, coming in contact with the flame, ignites and explodes. In some instances the firemen remain pent up a considerable time in the greatest suspense, owing to some accidental circumstance having put the candle out before it reaches the *pot-hole*, when they are fearful of venturing, from the uncertainty of what may be the event. In many instances it has been found necessary to explode these lodgments three times a day, at each time clearing the mines of all the workmen except the firemen; the necessity of which has been occasioned by the miners cutting down strata or measures of coal, so as to render the roof higher

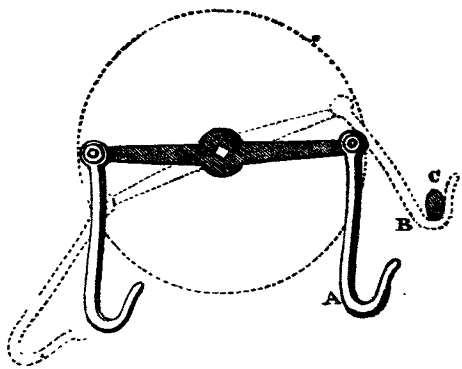
than the general run, of six or eight feet seams, and by these means making the extra elevation too great to be effected by the diluting current. In fact, where the roof of a coal mine (where the seam is thirty-six feet thick,) is cut down, no means but the firing process could suspend for a single day the destructive effects produced by an explosion of the whole mine. To obviate the dangers and difficulties of the firing process, Mr. James Ryan, of Netherton colliery, near Durham, who had been for many years engaged in working mines, invented, in lieu of it, a simple, effectual, and economical system of ventilation, by which the fire-damp, or inflammable gas, was carried off upwards from the mine; whilst by another arrangement he caused the carbonic acid gas (or choke-damp) to pass off into the water level. In attempting to get his plans of ventilation tried at various mines, he met with the most stubborn opposition; and although in every instance in which he was allowed to introduce his system, he was eminently successful, yet, from the misrepresentations of ignorance and jealousy, his system of ventilation has been adopted in very few mines, and the firing process is still very generally resorted to. Mr. Wood, of Summer Hill Grove, Northumberland, has however invented an apparatus by which the firing may be effected without any *personal* danger. The annexed diagram represents the interior



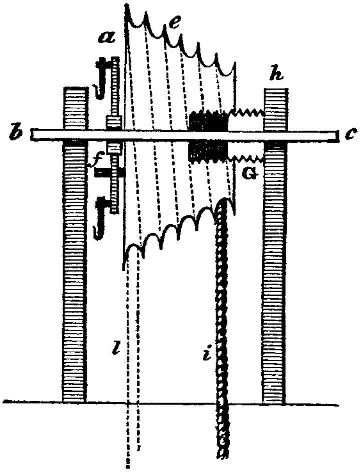
of a coal mine in perspective, with Mr. Wood's apparatus employed in igniting the gas. It consists of a common Dutch striking clock, in which the descent of a weight at a previously determined hour raises a lever having a counterbalance weight: this lever acting upon another lever, causes a match, charged with

oxymuriate of potash, to be dipped into a bottle containing sulphuric acid; the counterbalance weight on the first lever immediately afterwards draws the match out of the bottle, when the contact of the air causes the match to ignite, and to set fire to a train of combustible matter connected with it, consisting of cotton or tow saturated with spirits of turpentine. *a* represents the weight of the clock, which is set to go off at the time denoted; a projecting piece at the bottom of the weight presses in its descent upon one extremity of a lever, which turns upon a fulcrum at *b*: the other end of this lever is provided with a roller *c*, which raises the loaded end *d* of another lever, supported upon a standard at *e*; at *f* is a rod attached by a joint to the other extremity of the second lever, and at the lower end it is jointed to a small block, to which is fixed the match. To the match are attached some loosely twisted filaments of cotton, which are carried upward, and wound round an iron rod as loosely as possible, so as to form a large bunch of easily ignitable matter, to further which the whole is saturated with spirits of turpentine: the iron rod containing the bunch of cotton slides up and down in a fixed standard *i*, as represented; and from this point a train is made to other parts of the mine, where the inflammable gas may have collected in a detached volume, by means of strips of brown paper dipped in oil of turpentine, which are strung together and suspended in festoons on standards fixed in the ground. The clock being set to go off when all the workmen are absent from the mine or at rest, the weight operates upon the lever at the precise period determined upon, ignites the match and the train, and thus destroys all the inflammable gas.

The following is a simple and useful contrivance for the prevention of accidents in raising men or minerals out of mines, by the ropes "running wild," as it is termed, and for which the inventor, Mr. E. Speers, was presented with the silver Vulcan medal by the Society of Arts. A bar is fixed on the end of an axis. Two hooks, as A, swing freely on the ends of this bar; C is a short bar or stop, projecting from the frame of the machine, for the hook to catch hold of. When the bar revolves at a moderate rate, the hooks constantly hang down by their own weight, and keep clear of the stop C; but when it revolves with a dangerous rapidity, the centrifugal force causes the hooks to diverge from their pendant position, and one of them catches hold of the check-bar C, (as shown by dotted lines,) which stops the machine instantly.



A correspondent in the *Register of Arts* proposes the following modification of this contrivance, by which the shock occasioned by the sudden stoppage of the machinery is avoided, and the further advantage gained, that when the velocity of the machinery is so far reduced as to avoid danger, the machinery will not stop, but will recommence motion of itself. In the engraving in the next page, *a* is a section of Mr. Speers' check-hooks; the bar to which the hooks are suspended turns with the axle *b c*; *e* is a conical pulley, with grooves cut in a spiral direction, as represented in the section; this pulley turns on the axle, and not with it, like the bar *a*; out of this pulley projects the check-pin *f*. G is a screw fixed to the frame *h*, which fits into the pulley *e*, so as to enter it as soon as the pulley is made to revolve in the same direction as the bar *a*. *i* is a cord fixed to the pulley *e*, so as to be wound round all the grooves when the pulley is turned; to the end of it is fixed a weight, the size of which must



be regulated according to the velocity with which the machine is required to work. From inspection of the plan it will be seen that when the check-hooks, by the too rapid revolution of the check-bar *a*, have diverged so far from their pendant position as to lay hold of the check-pin *f*, the pulley *e* will be drawn round in the same direction as the bar *a*, and will wind the weight suspended by the cord *i* until the cord reaches the uppermost groove, as at *l*, when the velocity of the machinery will be greatly moderated, at which time the pulley *e* will have advanced so far along the screw G as to draw the check-pin out of the check-hooks, when the machinery will proceed in a regular way, and the cord *i*, by the descent of the weight attached to it, will reverse the motion of the pulley, and return it to its original position, as shown at *i*, where it will be always ready to regulate the machinery when the check-hooks, by their centrifugal force, come in contact with the check-pin *f*.

COBALT. A metal of a whitish grey colour, similar to tin, but with little brilliance. It is brittle and easy to pulverize, but difficult to fuse, requiring a temperature equal to that which is necessary to melt cast iron. Like iron it is attracted by the magnet In its metallic state it is of little use, but its oxide is employed to impart a blue colour to fusible and vitreous substances. See Zaffre and Smalts.

COCOA-NUT is a native of most of the tropical countries; the tree is from 40 to 60 feet high, the leaves from 10 to 15 feet long, and 3 feet broad. The fruit is about the size of a man's head; it contains a white kernel, the hollow of which is filled with a milky juice. The uses of the cocoa-nut tree are numerous and important. Its trunk is made into boats and water-gutters; and in house-building, the leaves serve for thatch, and are wrought into mats and baskets; likewise as a substitute for paper in writing upon. The fibrous husk of the shell, after being soaked in water, is beaten into oakum, spun into a variety of yarns, woven into sail-cloth, and twisted into ropes and cables even for the largest ships. The hard shell is polished and formed into cups, powder-boxes, &c.

COG. The tooth of a wheel, by which it acts on another.

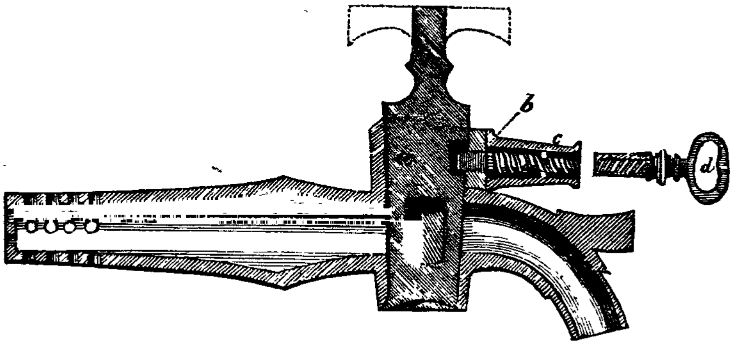
CLARION. A kind of trumpet, whose tube is narrower, and its tone acuter and shriller, than that of the common trumpet.

COCHINEAL. An insect which feeds on the Oactus opuntia, or prickly pear of Mexico and other parts of South America. In the dried state in which it is brought to Europe it resembles grains about one-eighth of an inch long, with one side round and transversely wrinkled, and the other rather flat. The colour is of a purplish grey; the grey is owing to a powder which covers it naturally; the purple tinge proceeds from the colour extracted by the water in which it has been killed. The rich crimson colouring matter which it yields does not appear to be injured by long keeping in a dry place, some cochineal of 130 years' old having been found to produce the same effects as new. The colouring matter may be extracted either by water or alcohol. Alum was formerly the only substance used to fix the dye of cochineal. About the year 1650, Drebdel, a German chemist, discovered the effect of tin in heightening the colour. The solution of tin in different acids will produce crimson, purple, violet, and scarlet of various kinds. See Carmine.

COCK. An instrument for permitting or arresting the flow of a liquid at

pleasure. They generally consist of a short tube communicating with the cask containing the liquid, and having a plug ground into it near the middle, and standing at right angles to it. This plug has a hole through it, which being brought to coincide with the bore of the pipe, the plug offers no obstruction to the liquid, but by turning the plug one quarter round, the solid part of the plug stands across the bore of the pipe, and stops the passage of the liquid. Numerous peculiarities are to be found in the construction of cocks, to adapt them to particular uses; some of these we shall proceed to notice.

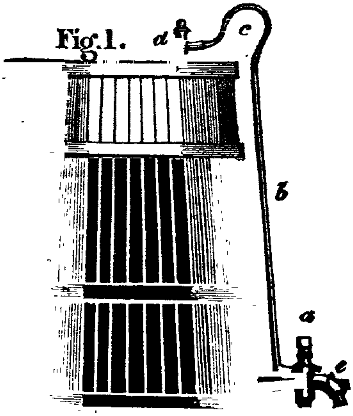
The annexed figure represents in section, an improved lock-cock for liquor-casks, invented by Mr. W. Russel. Numerous patents have been taken out for



lock-cocks; but few of these inventions, we think, are equal to Mr. Russel's for simplicity and security. The engraving represents the cock shut and locked. A square hole being cut through the barrel and into the plug *a*, a movable steady pin or bolt *b*, with a shoulder to limit its action, is fitted into it, passing through the barrel into the plug; the opposite end terminates in a screw, over which is a spiral spring resting on the shoulder; a turned brass socket *c*, having also a shoulder about midway to press upon the spiral spring, is then put over all, and secured to the barrel either by solder or screws; if by the latter only, the notches in the heads must be filed away for obvious reasons. To open the cock, or rather to withdraw the bolt, the screwed socket key must be introduced, when about two turns will sufficiently compress the spring and withdraw the bolt, and the cock may then be opened and shut at discretion, while the screw-key remains in the position described. When the key is withdrawn, the action of the spring upon the plug forces the bolt into the aperture of the plug upon shutting the cock.

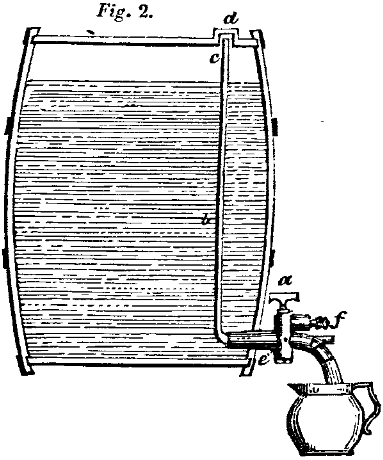
The accompanying figures represent another contrivance of Mr. Russel's, which he has named a "hydro-pneumatic liquor-cock, and air-vent attached," the object of which is to admit the air to press upon the surface of the liquor, so as to cause it to flow upon opening the cock, but to shut off all communication between the atmosphere and the interior of the vessel when the cock is closed, by which the strength of the liquor is preserved, and it is prevented from speedily turning sour. *Fig.* 1 is a view of the cock with the air tube applied externally. The plug, in addition to the aperture for the passage of

Fig. 1.

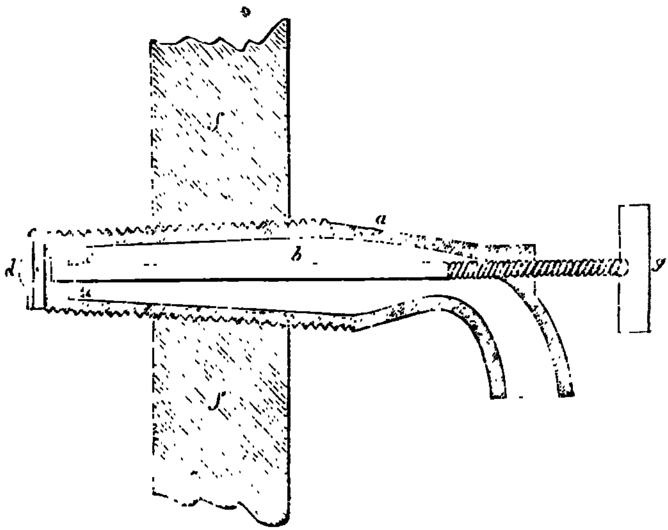


the liquor, has a smaller one placed above it for the transmission of the air: upon turning the cock to draw off, the air enters the smaller passage, and passing along the bent tube *b* enters the vat above the surface of the liquor through the metal plug or ferrule *d*. *Fig.* 2 is a section of a barrel showing another modification of the apparatus, by which the air-tube is placed internally; this method is considered preferable in brewers' or distillers' large vessels, and in situations where the tube, if applied externally, would be liable to injury. Letters *a b c d* and *e* apply to the same parts as in *Fig.* 1; but the aperture for the admission of air in this cock is situated at the side (at *e*), in order to show the application of the invention to one of Mr. Russel's lock-cocks, already described.

Fig. 2.



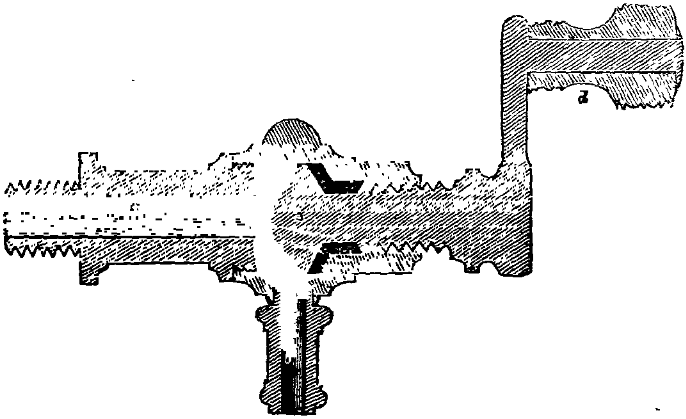
The following cut represents a cock of simple construction, in which there is no plug requiring grinding into its seat, and which may be entirely formed of cast iron, which is at once cheaper and not pernicious like brass. *a* is the



barrel; *b* a small rod having a screw cut on the end *g*, which works in a corresponding screw cut in the nose of the cock; the other end of the rod passes through a guide-piece *e* (perforated with numerous holes, to allow an easy passage to the liquor), and through a leather washer, at the back of which is an iron washer, against which the rod is rivetted; and according to the direction in which the screw is turned, the leather washer is either pressed against the end of the cock, thereby closing the aperture, or it recedes from it, and opens the passage. *ff* is a section of the cask into which the cock is screwed.

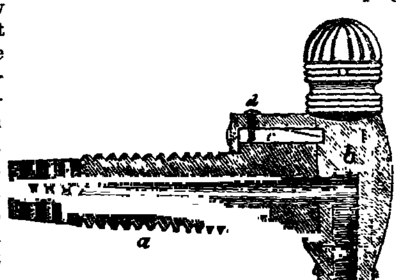
Another cock, in some respects resembling the preceding, but requiring

greater accuracy of workmanship, is shown in the following figure. *a* is the barrel, bored out cylindrical, and the interior end faced or filed square; *b* the nozzle; *c* a conical plug formed upon one end of a screw; *d* a handle upon the other end of the screw, by turning which the plug may be made to close the



cylindrical passage *a*, but when drawn back to the fullest extent, it leaves a clear passage for the liquor. A great objection to metallic cocks is their liability to corrosion in liquors containing any portion of acid, by which means the plug becomes loose in its seat, and in many instances a poisonous solution of the metal is formed in the liquor. These evils are avoided in Ridgway's porcelain cocks, which are not liable to corrosion in the strongest acids, at the same time they are very firm and substantial, being formed of the strongest porcelain or stone ware.

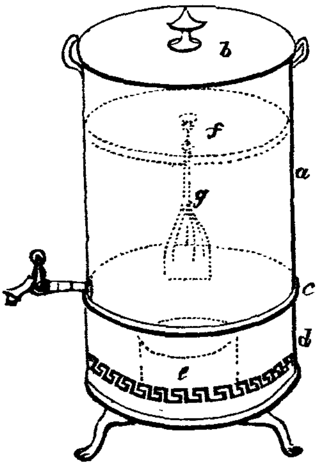
The forms of the cock are somewhat new, as well as the interior construction. The annexed diagram gives a section (excepting the upper or handle part of the plug,) of the form most approved by the patentees. *a* is the long tube, with a screw thread cut upon its external surface for the purpose of being screwed into the barrel; *b* the plug accurately ground, and fitted into its place; in the plug a vertical perforation is made by boring, equal to the diameter of that in the long tube, and another hole at right angles to the former to communicate with the vertical perforation and with the long tube, when the plug is turned in the direction shown, for drawing off the liquor. To secure the plug in its place, and to produce a uniform action, it has a groove made three-quarters round it, for receiving the end of the bolt *c* which is fastened by the screw *d*. See Valves.



COFFEE is the seed contained in a berry, the produce of a moderate sized tree called the *Coffea Arabicum*, and which has also been named *Jasminum Arabicum*. This tree grows erect, with a single stem, to the height of from eight to twelve feet, and has long, undivided, slender branches, bending downwards, these are furnished with evergreen leaves, not unlike those of the bay tree. The blossoms are white, sitting on short footstalks, and resembling a cherry, and having a pale, insipid, and somewhat glutinous pulp, inclosing two hard oval seeds, each about the size of an ordinary pea. One side of the seed is convex, while the other is flat, and has a little straight furrow inscribed through

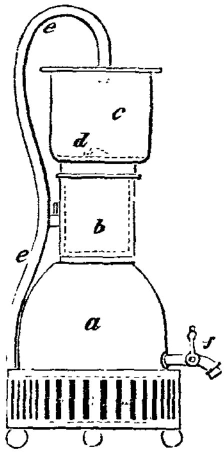
its longest dimensions; while growing, the flat sides of the seed are towards each other. These seeds are immediately covered by a cartilaginous membrane, which has received the name of *the parchment*. The trees begin bearing when they are two years old; in their third year they are in full bearing. The aspect of a coffee plantation during the period of flowering, which does not last longer than one or two days, is very interesting. In one night the blossoms expand themselves so profusely as to present the same appearance which has sometimes been witnessed in England when a casual snow-storm at the close of autumn has loaded the trees while still furnished with their full complement of foliage. The seeds are known to be ripe when the berries assume a dark red colour, and if then not gathered will drop from the trees. The planters in Arabia do not pluck the fruit, but place cloths for its reception beneath the trees, which they shake, and the ripened berries drop readily. These are afterwards spread upon mats, and exposed to the sun's rays until perfectly dry, when the husk is broken with large heavy rollers, made either of wood or stone. The coffee thus cleared of its husk is again dried thoroughly in the sun, that it may not be liable to heat when packed for shipment. The method employed in the West Indies differs from this. Negroes are set to gather such of the berries as are sufficiently ripe, and for this purpose are provided each with a canvass bag, having an iron ring or hoop at its mouth to keep it always distended, and this bag is slung round the neck so as to leave both hands at liberty. As often as this bag is filled, the contents are transferred to a large basket placed conveniently for the purpose. It is the usual calculation, that each bushel of ripe berries will yield ten pounds' weight merchantable coffee. In curing coffee it is sometimes usual to expose the berries to the sun's rays, in layers five or six inches deep, on a platform. By this means the pulp ferments in a few days; and having thus thrown off a strong acidulous moisture, dries gradually during about three weeks: the husks are afterwards separated from the seeds in a mill. Other planters remove the pulp from the seeds as soon as the berries are gathered. The pulping-mill used for this purpose consists of a horizontal fluted roller, turned by a crank, and acting against a movable breast-board, so placed as to prevent the passage of whole berries between itself and the roller. The pulp is then separated from the seeds by washing them, and the latter are spread out in the sun to dry. It is then necessary to remove the membranous skin or parchment, which is effected by means of heavy rollers running in a trough wherein the seeds are put. This mill is worked by cattle. The seeds are afterwards winnowed to separate the chaff; and if any among them appear to have escaped the action of the roller, they are again passed through the mill. The roasting of coffee for use is a process that requires some nicety; if burned, much of the fine aromatic flavour will be destroyed, and a disagreeable bitter taste substituted. The roasting is now usually performed in a cylindrical vessel, which is continually turned upon its axis over the fire-place, in order to prevent the too great heating of any one part, and to accomplish the continual shifting of the contents. Coffee should never be kept for any length of time after it has been roasted, and should never be ground until it is required for infusion, or some portion of its fine flavour will be dissipated. Count Rumford, who paid great attention to the management and preparation of coffee, used to preserve the aromatic fragrance of that which had been ground, by placing it into a cylindrical metallic box, which was covered by an accurately fitting piston in the inside, being well closed by a nicely adjusted cover on the outside. An improved apparatus for roasting coffee was patented by Mr. Evans in 1824, the operation of which, it is said, confers a flavour similar to that from Mocha to West India coffee; and, owing to the retention of the essential oil, a greater weight of roasted coffee is obtained from a given weight of the raw material. The art, according to Mr. Evans's practice, seems to consist in the abstraction of the aqueous and acidulous matter, without volatilizing the essential oil, upon which mainly depend the flavour and agreeable qualities of coffee. The apparatus consists of an elliptical iron retort, set in brick-work, over a furnace; the retort is made to revolve upon hollow axes, one of them serving as an exit passage for the vapour, which is delivered therefrom into a

convoluted pipe, immersed in cold water, and is thereby condensed; the other hollow axis is for the convenience of introducing the "examiner," which is a perforated tube, used to draw out a sample of coffee under operation, while it serves also as a safety valve in case of the vapour accumulating in too great force. A series of the retorts are placed over their respective furnaces, and they are caused to revolve by geering connected to their axes, to which motion is given by a steam engine, or any other convenient power. When the roasting has been found complete, the retorts are lifted out of their apertures over the furnace, and turned over upon one of their axes, which is provided with an ingenious swivel bearing for that purpose; the coffee is then discharged, and the operation renewed upon a fresh quantity. In the ordinary method of roasting coffee an acetic acid is generated, which is diffused in the liquor if the infusion remains long. To obviate this inconvenience, an apparatus was contrived called a *biggin*, in which the coffee is put into a bag suspended to the rim of the vessel, and boiling water having been poured through, it is separated and removed from the water, which remains pretty free from acid, and combined with much aromatic fragrance. In coffee roasted by Evans's distillatory process, before mentioned, the acetic acid is mainly got rid of, and therefore the same precautions that are used in the biggin are not necessary, and a richer infusion may be made by allowing the coffee to soak longer in the water; but as the fragrant principle is of a very volatile nature, Mr. Evans contrived the following apparatus, which is found to answer the objects intended extremely well, and will serve for the foundation of a machine of a more elegant exterior. The body *a* of the vessel is of a cylindrical form; it has a cover *b* at top, and at *c* a bottom, under which is a stand or furnace *d* containing a lamp *e*; at *f* is a floating piston with a hook underneath for suspending the ground coffee in a bag *g*. The floating piston is made of two thin metal plates soldered together, with a hollow space between them capable of holding a sufficient quantity of air to render itself and the bag of coffee buoyant. The piston is accurately fitted to the cylinder, but so as to allow it to rise and fall freely with the surface of the liquid in which it floats, and thus preserve the infusion from the contact of air, and there is only an extremely fine circular line of liquor at the edges exposed; the heat and the aroma of the infusion is thus preserved until the last cup is drawn off. When coffee is ground to a fine powder, and placed loosely among the water, the particles are a long time subsiding, and are easily disturbed after having settled. To clear the liquid it has been usual to add a few shreds of isinglass or other animal gelatine. The inconvenience of this process probably caused the introduction of the bag, which is however not without some disadvantages; among which may be mentioned the trouble of cleansing, and the imperfect solution of a portion of the extractive matter when the coffee lies in so dense a mass. It has accordingly been suggested to place the coffee between two flat perforated plates, at nearly the bottom of the vessel; the water should be supplied by a tube extending from the top of the vessel to the bottom, from whence it will ascend through the strainers, and the coffee contained between them, which being unconfined, every particle will be kept in agitation by the boiling water, and be thoroughly operated upon: to this arrangement the floating piston, before described, may be advantageously added.



Since the foregoing suggestions were made, Mr. Jones, of the Strand, has

introduced a coffee-pot on the principle which is represented in the annexed cut. *a* is a vessel placed over a lamp furnace, into which the requisite quantity of water is put; *b* is a double vessel, the internal one consisting of a perforated metal cup to hold the ground coffee; *c* is another recipient fitting over *b*, and having a valve at *d*. When the water in *a* boils, the steam ascends amongst the coffee in *b*; and when the steam accumulates in sufficient force, its pressure upon the surface of the water in *a* causes the boiling fluid to ascend the pipe *e e*, and to be discharged into the vessel *c*; the lamp may then be blown out, and the liquid will percolate through the coffee in *a*, and the perforated strainer in its descent to the vessel *a*, which will thus become filled with a filtered and aromatic infusion.



COFFER DAM. An enclosure constructed for the purpose of laying the foundations of bridges, piers, &c. formed by two or more rows of piles driven close together, with clay thrown in between the rows, the heads of the piles rising above high water mark, and thus forming a barrier to exclude the water.

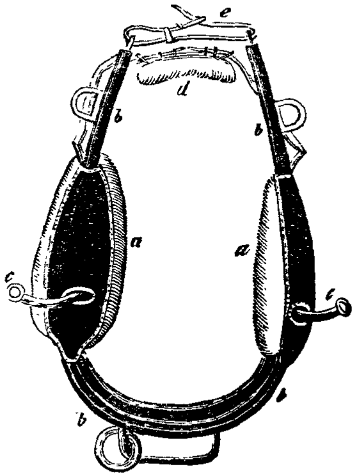
COHESION, or Attraction of Cohesion, is that power by which the particles of bodies are held together. The absolute cohesion of solids is measured by the force necessary to tear them asunder; heat is excited at the same time. At the chain cable manufactory of Capt. Brown, a cylindrical bar of iron, of 1¼ inches diameter, was drawn asunder by a force of 43 tons. Before the rupture the bar lengthened about 5 inches, and was reduced nearly three-eighths of an inch at the part where the fracture took place, which became heated to a degree unpleasant, if not painful, to the hand. The cohesive force of metal is considerably increased by hammering, rolling, or drawing. The following table shows the cohesive strength of a square inch in lbs. avoirdupois, or the force necessary to pull asunder a square inch of the various substances named therein.

	lbs.
Copper, cast	22,000
Ditto, wire	61,000
Gold wire	31,000
Iron, cast	30,000 to 50,000
Ditto (German)	68,000
Ditto, bar	60,000 to 80,000
Ditto (German)	60,000 to 90,000
Ditto, wire	113,000
Platinum wire	56,000
Silver ditto	40,000
Ash	17,000
Beech	17,000
Deal (Norway spruce)	18,000
Ditto (English)	7,000
Elm	13,000
Oak	11,000 to 16,000
Hemp fibres glued together	92,000

COINAGE, or Coining, is the art of making metallic money. See Mint.

COLCHICUM AUTUMNALE. A medicinal plant, the vinous infusion of whose root has been shown by Sir E. Home to possess specific powers of alleviating gout. The sediment of the infusion ought to be removed by filtration, as it occasions gripes, sickness, and vomiting.

COLLAR. A part of a horse's harness which surrounds his neck, and to which the traces are attached by which he draws. It ordinarily consists of a stuffed leather pad, on which rest two curved bars called the *hames*, united at the lower ends by a few links of chain, and drawn together at top by a strap and buckle; but from the collapsing of the hames, the shoulders of the horses frequently become rung, which induces many to give the preference to breastings rather than collars. In Mr. Lukin's improved horse collars the hame is made in one piece, which, from its elasticity, has a tendency to expand instead of collapsing, and the pads upon it are not fixed immovably, but turn round upon the hames as an axis, by which means the pressure adapts itself to the motion of the horse, and materially reduces the chafing against his shoulders. The annexed cut represents one of these collars. *a a* represent the pads, one turned partly round upon the hames *b b b* to show their action; *c c* are clips for the traces; *d* a small pad which lies over the horse's neck, and *e* the strap by which the hames are contracted in any required degree.

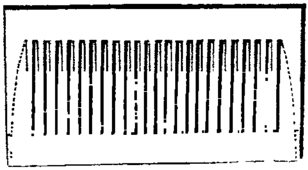


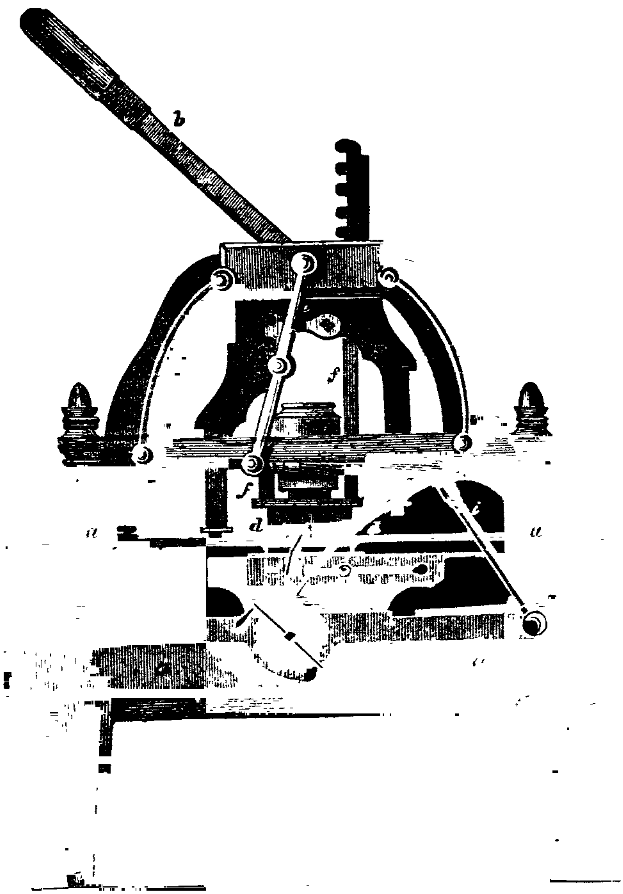
COLOUR is that property in bodies which, when acted upon by light, impresses the mind, through the agency of our sight, with those sensations which we denominate colour. The light of the sun, which seems perfectly homogeneal and white, is universally acknowledged to be composed of no fewer than seven different colours, viz. red, orange, yellow, green, blue, purple, and violet. A body which appears to be of a red colour has the property of reflecting the red rays more powerfully than any of the others, and so of the orange, yellow, green, &c. A body which is of a black colour, instead of reflecting, absorbs all or the greatest part of the rays that fall upon it; and, on the contrary, a body which appears to be white reflects the greatest part of the rays indiscriminately, without separating the one from the other. See Painting and Pigments.

COMB MAKING. The process of comb making is usually conducted as follows. The material of which the comb is formed is first reduced to thin smooth plates of an even thickness. The workman who cuts the teeth then fastens one of these plates in a clamp or vice, and proceeds to cut the teeth by means of a double saw, of which each blade is somewhat like the small one with which joiners and cabinet-makers cut their fine work. As this instrument leaves the work square, and in rather a rough state, particularly in the inside edge of each tooth, it is followed by another about the size and shape of a case-knife, having teeth like a file on each flat side. After this, two others of the same shape, but each finer cut than the former, follow. One stroke on each side of the comb is then given with a rasping tool, to take off any roughness that may remain on the sides of the teeth, after which they are polished by rubbing them with rotten stone, and oil spread upon a piece of buff leather. With the simple apparatus above described, delicate ivory combs, containing from fifty to sixty teeth in the inch, are cut. Mr. Bunday's machine for cutting the teeth of combs is constructed as follows: upon an arbor driven by a treadle, is fixed a number of circular steel cutters, corresponding to the notches intended to be cut in the comb. These cutters, which are about two inches diameter, and all exactly equal in thickness, have brass washers between them, and are also kept regularly asunder just above the place where the comb enters, by steel guides fixed in a stationary frame. The comb is firmly secured to a horizontal

sliding block or carriage, which is made to advance towards the centre of the axis of the cutters, by means of a screw turned either by hand or by a band-wheel fastened upon its axis. The combs are pointed by applying them to an arbor, driven by a crank, and clothed with cutters with chamfered edges.

Some improvements have been introduced in the rotatory comb cutting machines by Mr. Lyne, who has also invented a machine by which two combs are cut at once out of any tough material, as horn or tortoiseshell: the parts cut out from between the teeth of one comb forming the teeth of the other comb in the manner shewn in the annexed diagram; by which means the waste of material occasioned in cutting combs by the ordinary process is avoided. This machine is represented in the accompanying engraving. *a a* is the frame of the machine, made of cast iron; *b*, a lever, which, by a pinion upon its axis, gives





an alternating motion to the racks *c c*; *e* is the cutter in its carriage, which is attached to a strong helical spring, contained in the cylindrical box, and is

seen immediately over it. At each extremity of the cutter is a small chisel *d d*, set upon sliding rods, so that their distance asunder may be always equal to the length of the cutter *e*; these chisels make the end cut, by which the teeth of the one comb are separated from the back of the other comb. Beneath the cutters is a traversing carriage, upon which the horn or tortoiseshell is firmly secured by screws: it is made hollow to admit of a heated iron being introduced within it, in order to soften slightly the horn or tortoiseshell, and render it less brittle. This carriage is advanced along a chase mortise, fixed upon the bed of the machine by means of a screw, upon one end of which is a ratchet wheel, which is moved by the compound levers *i i i*. The fineness of the teeth of the combs is regulated by the teeth in the ratchet wheel, which is accordingly changed with the nature of the work, and a handle is placed on the axis of the ratchet wheel for the purpose of bringing back the frame after a comb has been cut. The operation of the machine is as follows:—the alternating motion of the lever *b* backwards and forwards alternately raises and depresses the racks *c c*; the horns or curved projections in the middle of these racks bring down the cutter *e*, by which one side of a tooth is cut, whilst the extremities of the racks depress one of the chisels *d*, which makes the cut at the end of the tooth. The cutter *e* is returned during the rise of the rack, by the spring contained within the cylindrical box, and the chisels *d* by the spring of the rods upon which they are set. In order to give the tapered form to each tooth, and to reverse them successively upon the opposite side of each of the racks to that shown in the engraving, is a small inclined plane or cam, which, on the descent of the rack acting upon the vertical bars *f f* attached one to each end of the cutter frame, causes the cutter to change its position, and to make angular instead of parallel incisions.

COMBUSTION. The disengagement of heat and light which accompanies chemical combination. Combustion was for a long time held to be the disengagement or development of a certain air supposed to be contained in all combustible bodies, and to which the name of *phlogiston* was assigned; and bodies which had undergone combustion were said to be dephlogisticated, or to have parted with their phlogiston. This hypothesis, notwithstanding the numerous facts at variance with it, and particularly the familiar one that metallic oxides formed by combustion increase in weight, which could not be the case if combustion consisted in depriving them of any substance previously contained in them, was zealously maintained by many philosophers long after the brilliant discoveries of Scheele, Cavendish, and Priestley, as to the nature of atmospheric air, and against the theory of Lavoisier, founded upon these discoveries, and upon Dr. Black's theory of latent heat. According to the theory of Lavoisier, the light and heat emanate from the oxygenous portion of the atmosphere at the moment of its fixation with inflammable bodies; and succeeding chemists of his school, enlarging upon this idea, have ranged all substances under two classes, viz. combustibles, and supporters of combustion. But this theory, although much more consistent with most of the phenomena of combustion, is still insufficient to account for some of them, and the distinction between combustibles and supporters of combustion appears to be altogether imaginary, for one substance is frequently in both capacities, being at one time *apparently* a supporter, and at another time a combustible. Thus, sulphuretted hydrogen is a combustible with oxygen, and chlorine a supporter with potassium; and sulphur, with chlorine and oxygen, acts as a combustible, but with the metals it becomes a supporter. Nor can we ascribe the appearances to an extrusion of latent heat in consequence of condensation: the protoxide of chlorine, a body destitute of any combustible constituent at the instant of decomposition, evolves light and heat with explosive violence, and its volume becomes one-fifth greater; and the chlorates and nitrates in like manner treated with charcoal, sulphur, or metals, detonate or deflagrate, while the volume of the combining substances is greatly enlarged. Neither can the heat evolved in combustion be attributed to a diminished capacity for heat in the resulting substances, for in the greatest number of cases there is no diminution of capacity of the compounds formed. For example, the combination of oxygen and

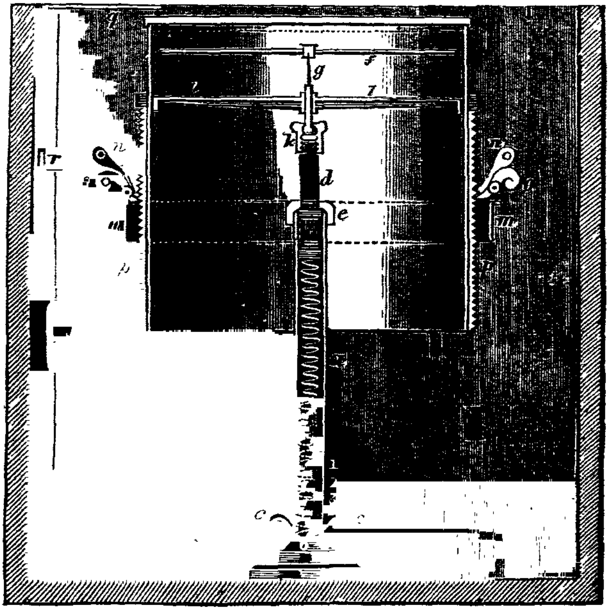
hydrogen, or of sulphur and lead, produces no greater alteration in the capacity of water, or of the sulphuret of lead, than the combination of oxygen with copper, lead, or silver, or of sulphur with carbon, produces in the capacities of the oxides of these metals, or of carburet of sulphur. The preceding, and numerous similar facts, prove that combustion is not necessarily dependent upon the agency of oxygen; that the evolution of the heat is not to be ascribed simply to a gas parting with its latent store of that ethereal fluid on its fixation or combustion; and that no peculiar substance, or form of matter, is necessary for producing the effect, but that it is a general result of the actions of any substances, possessed of strong chemical attractions, or of different electrical relations; and that it takes place in all cases in which a violent motion can be conceived to be communicated to the corpuscles of bodies. For this view of the subject the world is indebted to the masterly mind and deep and successful researches of Sir H. Davy. For a clear and comprehensive account of his experiments connected with this subject, together with his inferences therefrom, we refer the reader to Dr. Ure's *Chemical Dictionary*.

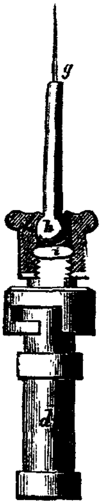
COMPASS. A nautical instrument, showing the direction in which a vessel is sailing, or the part of the horizon to which her head is directed. It consists of a flat bar of steel, which being repeatedly rubbed with a magnet or loadstone acquires the property of constantly taking a direction nearly corresponding with the meridian, when freely suspended from a thread, or upon a delicate pivot. Although as important consequences have flowed from the invention of the compass as from any other invention whatever, the name of the author of it, and even the age and country in which it had its origin, are points involved in the greatest obscurity. In Europe we are indebted for its use to B. Givaia, of Naples, who, towards the close of the twelfth, or about the commencement of the thirteenth century, observed that iron became polarized by contact with the loadstone; but most writers upon the subject agree that the compass was known long before that period to the Indians and Chinese; nay, in Bowles's *Spirit of Maritime Discovery*, it is attempted to be proved, by much "learned argument," that it was known to Noah, and formed part of the equipment of the ark. The compass is extensively used in surveying and mining, as well as in navigation; but there is in general this difference between them, that marine compasses have a circular card divided into thirty-two parts or points, and attached to the needle; but in those for other purposes the card is fixed to the bottom of the box, which is turned till the needle coincides with the north point of the card. Marine compasses are usually supported upon a pin of steel or brass, having a fine point, working in a socket of agate let into the centre of the needle or magnetized bar; the pin is fixed into the bottom of a circular box or basin, which is suspended by two pins turning in holes in a ring concentric with the circular box; this ring again is suspended by two pins at right angles to the former, the whole forming a universal joint. Besides the steering compass, there is another one made use of at sea, for the purpose of taking the sun's bearing, in order to ascertain the variation of the compass, or the difference between the true and magnetic north points, as also in taking the bearings of different objects in marine surveying; this is called the azimuth compass. The card, besides the thirty-two points, is accurately divided at the circumference into 360 degrees, and on the opposite sides of the compass-box are two sights, for taking accurately the bearing of an object, and a stud for stopping the card at the instant the bearing is obtained, so as to allow time for reading off the angle. The circular box is suspended within a square box, which latter is supported upon a pivot (on the top of a three-legged stand), so that the right vanes may be turned to any part of the horizon. Captain Phillips, R.N. has taken out a patent for an improved mode of mounting ship's compasses; the object of which is to prevent those derangements which sudden concussion occasions to these instruments, by which the card is frequently thrown off its central pivot, as is sometimes the case in stormy weather, or from firing guns, striking of steam-boat paddles, &c. The figure in the following page, *Fig.* 1, gives a vertical section of the improved compass. *a* is the standard formed of a hollow tube which incloses a long spiral spring, resting

upon a bearing at *b*; to this bearing are fixed two handles *c c*, by which it may be elevated within the standard, (compressing the spring,) and the bearing may rest

Fig. 1.

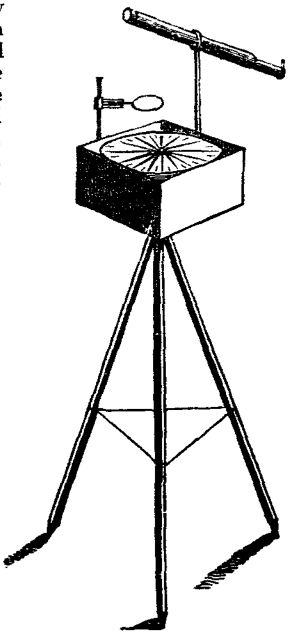
Fig. 2.





at any of the notches or recesses Nos. 1, 2, 3, 4, which are formed in opposite sides of the tube, to receive the handles *c c*. *d* is a short solid cylindrical piece, so fitted into the hollow standard as to slide freely within it, and resting upon the spiral spring; *e* is a cap fixed on to *a* by a bayonet joint, to prevent the spring from forcing the sliding piece *d* out of the standard; *f* is the compass-card, which rests upon the pivot *g*; this pivot passes through the cross bars *l l*, and the lower end is formed into a spherical knob, (better seen at *h*, *Fig.* 2, which exhibits the same parts upon a larger scale). This spherical knob rests upon a flat surface of agate, cornelian, or other hard stone *i*, which lies in a recess upon the top of the piece *d*, and is kept in its place by the cap *k* being screwed down upon it; the cap *k* is made concave in the upper part of it, to fit the spherical knob, so that the latter, resting at bottom upon a hard plane, and above in its hemispherical concavity, can turn freely in any direction. At *m m* is shown (black) the section of a leaden ring, which surrounds the compass-box, as is shown by the two parallel dotted lines. At *n n* are two handles fixed to the leaden ring, by which it may be shifted higher or lower on the case, and be fixed at any height at pleasure, by the palls *o o* dropping into the racks *p p*, which are screwed to opposite sides of the case. *q* is the steering, or "lubber's point," which is suspended upon a movable joint *r* as a centre of motion, and oscillates as a pendulum. This centre being placed so as to slide between two vertical guides, it may be raised or lowered at pleasure, and is retained in its place by the pressure of a spring in the centre. The lubber's point should be adjusted so as to be even with the upper edge of the compass, by raising or lowering the centre *r*, and the bob *s* should be shifted along the rod until it coincide with the centre of the leaden ring. If the motion of the compass-box, in a vertical direction, should be too violent, it is to be checked by raising the handles *c c* into one of the notches 1, 2, 3, 4, as may be required by circumstances. The oscillations of the compass-box are regulated by shifting

the leaden ring, raising it in blowing weather, and lowering it in fine weather. It frequently happens at sea that the sun is visible, although the horizon cannot be distinguished for fog and haze, in which case it becomes impracticable to take the sun's altitude, in order to determine the ship's place. This circumstance, at all times inconvenient, may, in some situations, be attended with the most fatal consequences. To obviate this difficulty, Lieut. G. Lindesay, R.N. proposes to take two bearings of the sun, as near noon as possible, noting the time elapsed by a good watch, and from these data to compute the sun's meridian altitude in the usual way, which will give the latitude and apparent time at the ship; and this latter, compared with the Greenwich time, will give the longitude. For taking the sun's bearing he proposes to attach to a common compass, mounted on a pivot at the summit of a tripod, a telescope, turning upon a joint, and a magnifying glass to read off the divisions, as shown in the annexed diagram. It appears to us that the common azimuth compass (with which all ships are or ought to be provided,) will be found much superior to the above contrivance, by which we fear it would be difficult to observe the bearing with sufficient accuracy.



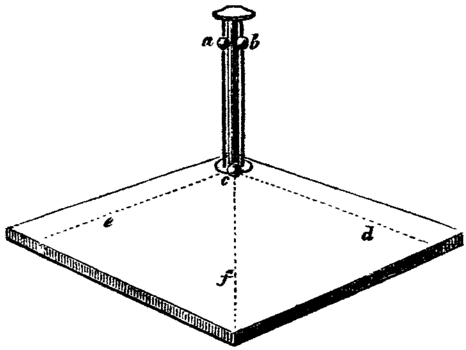
COMPASSES (Mathematical). Instruments for describing circles, measuring lines, &c. They are of various descriptions; the common consist of two sharp-pointed branches or legs, turning upon a hinge at top. Triangular compasses are constructed as the ordinary compasses, with the addition of a third leg turning upon a universal joint; they are used in laying down places on a chart, or measuring angles.

Beam Compasses are for the purpose of describing circles of considerable radius, and consist of a straight bar of wood or metal, of suitable length, furnished with a fixed point as a centre, and a movable tracing point, which may be set to any required radius.

Elliptical Compasses, likewise called a "trammel," for the purpose of describing ellipses, consist of a bar with a fixed tracing point, and two cursors, which can be set upon any part of the bar, and which have a sliding motion in two grooves cut in a piece of brass, which grooves intersect each other at right angles.

Proportional Compasses are composed of two flat bars pointed at the end, and having a groove down the middle, in any part of which can be set a steel pivot, held fast by a tightening screw, by which means the compasses can be divided into two parts, bearing any required proportion to each other, and which, turning upon the pivot in the manner of a pair of scissors, the angles at the opposite extremities will be proportional to the length of the respective parts.

COMPOSITION OF FORCES is the finding a single force which shall be equal to two or more given forces when acting in given directions, the principles of which may be thus illustrated. If two forces, moving in the direction of the two adjacent sides of a parallelogram with velocities proportional to the length of the sides of the said parallelogram, impinge upon a body, it will cause that body to move over the diagonal of the parallelogram in the same time that either of the forces singly would have impelled it along its corresponding side. This may be demonstrated experimentally by an ingenious apparatus, designed and executed by Mr. C. Holtzapfell, of Charing-cross, and which is exhibited



in the annexed engraving. The apparatus consists of a rectangular board, with a perpendicular brass pillar fixed in one corner. Two guide steel wires extend from the flanch at the bottom to the cap at the top, and sufficiently distant from the pillar to allow the two ivory balls *a* and *b* to descend upon them without touching the pillar. The board is made perfectly flat, varnished, and polished, and when used, must be placed perfectly level. At the point where two straight lines from the bottom of the guide wires would meet and make a right angle, a small hollow is made to receive a ball *c*. The weights of the balls *a* and *b* are adjusted to correspond with the length of the sides of the board; so that when the ball *a* is dropped, it will give an impulse to the ball *c*, and send it to the end of the board in the direction of the line *d* in the same time that the ball *b* would send it to the edge of the board in the direction *e*. If now both balls be dropped at the same instant from the same height, they will propel the ball in the diagonal *c f* of the parallelogram in the same time that one of them singly would have impelled it along one of the sides.

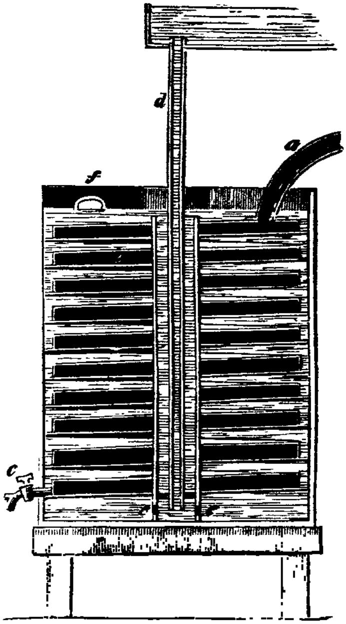
COMPRESSIBILITY, in Philosophy,—that quality of a body by which it yields to the pressure of another body, so as to be reduced within a smaller compass. The compressibility of liquids is still a matter of doubt with philosophers, although some consider the fact proved by the experiments of Mr. Canton, and, more lately, of Mr. Perkins. According to the former gentleman, the compression of

Spirits of wine, spec. grav.	846	was $\frac{66}{1,000,000}$	parts.
Rain water . .	,, 1000 . .	$\frac{46}{1,000,000}$	,,
Mercury . . .	,, 13,595 . .	$\frac{3}{1,000,000}$	,,

CONDENSATION. The art by which a body is rendered more dense, compact, and heavy. Condensation is by most writers distinguished from compression, by considering the latter as effected by mechanical force or pressure, and the former by cold, or the abstraction of heat.

CONDENSER. A vessel in which aqueous or spirituous vapours are reduced to a liquid form, either by injection of a quantity of cold water, as in the condenser of a steam-engine; or when this is inadmissible, as in the case of alcoholic vapour, by placing the condenser in another vessel, through which is maintained a constant current of water, the condenser being so constructed as to expose the steam or vapour in thin strata over an extended surface to the action of the cooling medium. The condensers employed by distillers are usually composed of a long tube of pure tin, or of copper tinned, formed into a series of concentric coils over one another, and from its shape denominated a worm; this is placed in a large vat, which is called the worm-tub. But when the distillation is carried on upon a large scale, the worm is not of a cylindric section, as it is not the form which is best adapted for the purpose of condensation; for on account of the large diameter of the tube, which then becomes necessary, that portion of vapour which occupies the centre of the tube is not brought into sufficiently intimate contact with the cooling surfaces, and therefore either escapes condensation, or requires a much larger quantity of water than would be otherwise necessary. Various arrangements have, in conse-

quence, been devised for presenting the vapour in extremely thin strata, so as to obtain a ready condensation with the least quantity of water. One invented by Mr. Wheeler, of High Wycomb, appears to us very judiciously arranged for this purpose; it is denominated by the inventor the Archimedes' Condenser, and is represented in the accompanying engraving. *a* is the pipe leading from the neck of the still, through which the vapours enter into the flat chambers *b b* (represented black). These chambers, owing to the sectional view, appear to be disconnected, but they are wound spirally round a central tube, and terminate at the cock *c*, where the condensed products pass off; *d* is a pipe leading from a reservoir of cold water to the bottom of the central tube, where it passes through holes represented at *e e* underneath the vapour chambers, and can only ascend in the vessel by passing successively through every coil, as each turn of the spiral is connected by the edge of one of its plates to the side of the containing vessel. The water thus heated in its progress flows out at the aperture *f* into a trough or pipe. By this arrangement it will be noticed that the hot vapour or fluid is constantly descending spirally an inclined plane, while the cold fluid is constantly ascending, almost in contact with the other, as they are only separated by a very thin plate, formed of the best conducting substance (copper). It will likewise be evident that two fluids, one cold and the other hot, may thus be made to exchange their temperatures. Thus, if cold water at 50° Fahr. be admitted at the bottom of the vessel, it will, when it arrives at the top, be nearly of the same temperature as the vapour or liquid (say 200°), which entered at the top, by having gradually abstracted the heat from the vapour or hot liquid in its progress. This being understood, it follows that the latter, having gradually parted with its heat in its descent, will become of the same, or nearly the same temperature at the termination of its course as the water, namely 50°, provided the liquids be admitted in their proper volume, which is easily regulated by the cocks.



CONE. A geometrical figure generated by the revolution of a right angled triangle upon one of its short sides, as an axis.

CONGELATION. The transition of a liquid to a solid state, in consequence of the abstraction of heat: thus metals, oil, water, &c., are said to congeal when they pass from a fluid to a solid state. With regard to fluids, congelation is the same as FREEZING, which see.

CONIC SECTIONS are the figures formed by the cutting of a cone by a plane; they are five in number, corresponding to the different positions of the cutting-plane. When the cutting-plane passes through the apex of the cone, and coincides with the axis, the section is a triangle. When the plane cuts the axis at right angles, the section is a circle. When the plane cutting the axis obliquely, and passing through both sides of the cone, the section is an ellipsis. When the plane cuts the axis in a line parallel to one side of the cone, the section is a parabola: and lastly, when the plane either does not cut the axis, or cutting it forms with it an angle less than that formed by the side with it, the section is an hyperbola. The term conic section is applied more peculiarly to the three last figures; and the doctrines of their several properties constitute

one principal branch of geometry, of great importance in astronomy and many other sciences See GEOMETRY.

CONOID. A solid produced by the circumvolution of the section of a cone about its axis, and consequently may be either an elliptical conoid (otherwise called a spheroid), a hyperbolical conoid, or a parabolical conoid.

CONTRACTED VEIN, in Hydraulics,—a term denoting the diminution which takes place in the diameter of a stream of water issuing from a vessel at a short distance from the discharging aperture, owing to the particles nearest the periphery experiencing greater attrition than the rest, and being retarded; in consequence of which the least diameter of the stream is to the diameter of the orifice, on an average as 1 to the square root of 2; and in computing the discharge of fluids, this proportion should be substituted for the real aperture.

CONTRATE WHEEL, or CROWN WHEEL. A wheel in which the teeth do not radiate from the axis, but stand at right angles to the arms, or parallel to the axis. It is chiefly used for clock-work.

COOLER, among brewers, distillers, &c. is a large shallow vessel in which liquids are exposed to cool.

COOPERING is the art of manufacturing casks, barrels, vats, and all kinds of circular or elliptic wooden vessels, that are bound together by hoops. There are several classes of coopers, some of whom carry on their peculiar branches distinctly, while others embrace the general manufacture in one establishment. The workmen, however, generally confine themselves to the particular line they have been brought up to, and in which they are consequently most expert. Thus we hear of "butt coopers," "rundlet coopers," "dry coopers," "white coopers," and "wine coopers." The work of the butt coopers chiefly consists in the manufacture and repair of casks for breweries, also puncheons and hogsheads. Their principal tools are very few, but they use these with so much dexterity and skill as to produce with surprising facility and dispatch the most solid, accurate, and substantial work. With an axe, an adze, two or three spoke shaves, and a bench, the cooper rapidly gives a new and perfect form to the material he operates upon. The bench consists simply of a stout plank 4 or 5 feet long, and 1 foot wide; it stands upon four feet, but considerably inclined, one end of the bench being usually about 2 feet high, and the other 6 or 8 inches lower. On the bench are fixed "stops" and "keeps," for the purpose of holding the staves or other work. This cooper has also a large plane, called a jointer, which is usually *fixed* with its face upwards, and against which he forces the staves to shoot their edges to a smooth surface, (whether those edges are required straight or curved,) in order to make the "joints" or joinings of the staves come into perfect and hardly-pressed contact, when they are brought together to form the vessel. To describe all, or even the leading operations, of the cooper, would be uninteresting, because it is so openly and universally practised. We shall therefore proceed to notice, and that briefly, the nature of the occupations of the other classes of coopers mentioned; and afterwards we shall insert some patented improvements in the art, that appear to be deserving of notice. The rundlet coopers make use of the same tools, or nearly so, as in the branch of the trade last described, but of less dimensions. Their work consists chiefly in the manufacture of bottles, and small casks, for holding the products of the distilleries, besides numerous other purposes. The dry coopers are employed in manufacturing sugar hogsheads, and casks of every size and quality, for holding dry goods; and as such vessels are seldom required air and water-tight, the workmanship is comparatively coarse to that of the butt and rundlet coopers, and the expense proportionally less. The white coopers manufacture all kinds of domestic utensils, such as are used for brewing on the small scale; for washing tubs, churns, pails, and a great variety of other work. To this branch of coopering is frequently added the coarser kinds of turnery for domestic use. The wine cooper's business consists chiefly in the removal and depositing of wines and spirits, which he is enabled to effect with greater security and convenience than other persons, who are not so intimately acquainted with the nature and strength of the vessels containing them. The bottling, storing,

and packing of wines, and other liquors, belong to this branch of trade, besides the making of all repairs and alterations in the butts or casks which may be found necessary. Although the manufacture of backs and vats appears of a similar character to other coopering, yet it is usually made a distinct branch of business, and is performed by persons who call themselves back and vat makers. From the variety of forms, and the immense strength required for some of the backs, as well as for the frame-work to support them, the knowledge and skill of the carpenter is almost constantly required, and not unfrequently the aid of the engineer. In America, and several parts of Europe, machinery has been extensively introduced to facilitate the labours of the cooper. In 1811, a patent was taken out by Messrs. Plasket and Brown for the following mode of operating; and as the exclusive privilege granted to those gentlemen is expired, those of our readers who may be so disposed are at liberty to adopt the mechanism employed, which is thus described in Dr. Gregory's *Mechanics.*

"First, the machinery for cutting the stave consists of a stout bench, having a board or platform annexed to it, capable of being moved endways, to which another board is connected, so arranged as to be moved across steadily by racks and pinions, or screws. The last board has a hollow part made in it, in which the stave-board may be laid, so that one edge of it may project clear beyond the edge of the first-mentioned board; a circular saw is placed either above or below the bench, having its axis at right angles to the line of motion of the first mentioned board, and opposed to the direction of the course of the projecting part of the stave-board; this circular saw is made flat when the straight-edged staves are to be cut, and is dished, or of a spherical shape, when staves with curved edges are wanted. The board first mentioned is moved either in a right line, or is made to assume a curved course, by being confined in its motion by curved grooves, or by curved rods moving against pins; and by the proper management of these sliding-boards, the stave-board is cut by the circular saw of the shape desired. The machinery next used consists of a large lathe, in which the cask is turned in a vertical position when it is of a large size (after it is formed in the usual manner from the staves prepared as above described), being either fixed in a great chuck placed beneath it, or in a cylindrical cage which surrounds it, fixed upon a strong upright arbor, and revolving between collars, where it serves the office of a mandrill. In this lathe the chime and groove for receiving the head are turned in the cask by the application of a proper tool. When the cask is small, the cage is made to turn in a horizontal position instead of revolving vertically. The third operation is to form the head, which is pinioned together as usual, after having the pin-holes made by piercers projecting from the mandrill of a lathe, the distances and depths of which holes are correctly regulated by gauges; it is then turned on a flat revolving table, from which points project to hold it fast, and against which it is held by another revolving piece that is screwed towards the first, where it is brought to the proper size of the cask by fit tools. The fourth operation is to turn the whole cask at the outside, for which purpose it is placed in a large lathe between two chucks, made to fit into the chines, and attached to the head by points; and then the surface of the cask is turned smooth by a spokeshave, or other fit instrument, held against it by a rest properly placed for the purpose. The patentees bend their wooden hoops for their casks in an expeditious manner, by fastening one end of them to the circumference of a wheel, and pressing them against the wheel as it is turned round; they also describe a method of forming the projecting part in the bung-staves of the small casks called bottles, by flat or concave circular saws, which cut the face of the stave on each side close up to the projection; and lastly, in giving motion to this machinery, the inventors use any of the usual first movers and millwork as may be necessary."

It is due to Mr. George Smart, of Westminster Bridge, to state, that, for some years previous to the date of the patent granted to Messrs. Plasket and Brown, he had in actual operation, on a very extensive scale, a similar arrangement of machinery for making small casks, particularly canteens for the army. The saws and other apparatus were of course more diminutive, but the accu-

racy of their work may be judged of when it is stated that there was no occasion to plane the edges of the staves to render the bottles water-tight, although submitted to a severe test.

COPAL. A hard, shining, transparent concrete juice, obtained from an American tree; but which, although it is commonly considered a gum, has neither the solubility in water common to gums, nor the solubility in alcohol common to resins, except in a very slight degree. It may be dissolved by digestion in linseed oil, rendered drying by quick lime, with a heat very little less than is sufficient to boil or decompose the oil. This solution, diluted with oil of turpentine, forms a beautiful transparent varnish, which, when properly applied, and slowly dried, is very hard and durable. It preserves and gives lustre to paintings, and greatly restores the decayed colours of old pictures, by filling up the cracks, and rendering the surfaces of reflected light more uniform. It has been observed by Mr. Sheldrake, that if powdered copal be triturated with a little camphor, it softens and becomes a coherent mass; and camphor, added either to alcohol or oil of turpentine, renders it a solvent of copal. Half an ounce of camphor is sufficient for a quart of oil of turpentine, which should be of good quality; and the copal, about the size of a walnut, should be broken into small pieces, but not to powder. The mixture should be set on a fire, so brisk as to make it boil almost immediately. The vessel should be of metal, strong, with a long neck, and capable of holding about two quarts. The mouth should be stopped with a cork, having a notch cut in it to prevent its bursting. Mr. Cornelius Varley (who has bestowed much judicious attention to the preparation of artists' materials), states that a good copal varnish may be prepared by pouring upon the purest lumps of copal, reduced to a fine mass in a mortar, colourless spirits of turpentine, to about one-third higher than the copal, and triturating the mixture occasionally in the course of the day. Next morning it may be poured off into a bottle for use. Successive portions of oil of turpentine may thus be worked with the same. Oil of lavender is stated to be alone a solvent of copal, which is probably owing to the camphor contained in the former. Camphorated oil of turpentine will also dissolve copal, but a mixture of camphor and alcohol effects it more readily.

COPPER is a metal of a reddish brown colour, hard, very malleable, ductile, and sonorous; of considerable tenacity, and of a specific gravity from 8.6 to 8.9. The good quality of copper is shown by its capability of alloying silver, without any diminution of its extensibility under the hammer or roller. For this reason the Swedish copper has a decided preference in the preparation of the alloys of gold and silver; and its superior purity has been found to render it far more durable when employed in the sheathing of ships, as well as for many other purposes. English copper is chiefly obtained from the mines of Cornwall and Devonshire, whence it is usually transported across the Bristol Channel to be smelted at the coal-works in South Wales. The ores consist chiefly of yellow copper ore, or copper pyrites, and the grey sulphuret of copper. The average produce in copper is said to be about 8½ parts from 100 of the ore. The ordinary processes of smelting consist of alternate calcinations and fusions in reverbatory furnaces of the usual construction. The calcining furnaces are furnished with four doors or openings, two on each side, for the convenience of stirring the ore and drawing it out of the furnace. They are commonly from 17 to 19 feet in length from the bridge to the flue, and from 14 to 16 feet in width, with a fire-place 5 feet by 3. The melting furnaces are usually about one-third the area of the calciners, but their fire-places are nearly as large, and they have only one door, and that in front. The charge of ore for a calcining furnace usually consists of about 3 tons, which is uniformly distributed over the bottom. When charged, the heat is gradually increased during twelve hours, until near the point of fusion, when the ore is discharged through holes in the bottom, and is suffered to lie underneath until it is sufficiently cool to be removed. With this calcined ore, which is in the form of a black powder, the melting furnace is charged, by spreading it over the bottom thereof. A few slags from the previous fusions are added, and the door

is closed and luted. When brought into fusion, the liquid mass is well stirred, and the oxides and earthy matters which float at the top are skimmed off through the front door by the smelters. When this first mass of metal has been freed from the last-mentioned impurities, the smelter lets down into the furnace a second charge of calcined ore, and proceeds with it in the same manner as with the first, repeating the charges until the furnace will hold no more, when a tapping-hole made in the side of the furnace is opened, and the metal runs through it into a pit filled with water, which causes the metal to become granulated, in which state it contains about one-third part of copper. The slags which have been cast in sand-moulds, are afterwards broken to ascertain if they contain any metal; the pieces that do are then remelted to separate it. When the ores are difficult of fusion, some fluor spar is added to the charge. The coarse metal obtained by the preceding process is then calcined by a similar treatment to that which the ore received. To oxidize the iron with which the copper is contaminated, the charge is allowed to remain twenty-four hours in the furnace, where it is repeatedly stirred and turned. The metal thus calcined is then to be melted again with some slags from the previous melting, to which may be added some pieces of furnace bottoms, which are impregnated with the metal. The slags from this operation are also skimmed off; they have a great specific gravity, being composed chiefly of the oxide of iron; they fuse readily, and act as fluxes to reduce further portions of the ore. The metal obtained from the second operation of the melting furnace, after the slag has been separated, is tapped off either into sand-moulds or into water. In the former plan the product is collected in a mass, and is called *blue metal;* in the latter it becomes granulated, and is denominated *fine metal.* The quantity of pure copper these products contain is about 60 per cent. The subsequent calcination and fusion of these last products is conducted by a repetition of the operations described; and the result of this third melting are pigs containing from 80 to 90 per cent. of pure metal. The fourth process is, for the most part, an oxidizing, or, as it is called, a *roasting* of the pigs obtained in the third. For this purpose the furnace is filled with the pigs to the extent of 25 or 30 cwt. which are exposed to the action of the air, while the heat is gradually increased to the melting point, which facilitates the expulsion of the volatile matters, and oxidizes the iron or other metallic substances that may remain. This operation is continued from 12 to 24 hours, according to the degree of purity of the pigs when put into the furnace; and when completed, the metal is brought to a state of fusion, and run out into sand beds. The ebullition of the metal arising from the extrication of the expanded air from the sand under the metal, caused the latter to assume in cooling a honey-comb texture internally, with a blistered surface; and, from this latter appearance, such copper is denominated *blistered copper.* The copper in this stage being freed from its more abundant contaminations is ready for the refining furnace, which is of a similar construction to the melting furnace, only that the bottom, instead of being of fire-brick, is a bed of sand, laid to incline to the furnace door, near to which a pool is formed for the purpose of lading out the refined copper. The furnace is charged with from three to five tons of the blistered pigs; the heat applied to them is at first moderate, and air is admitted so as to continue the oxidation, should the metal not be quite fine. When this charge is fused, and the slags skimmed off, an assay is taken by the refiner with a small ladle, and the metal broken in a vice. From the appearances of the metal both in and out of the furnace, the refiner judges whether it is in a sufficiently forward state to undergo the toughening process; previous to which the copper is of a deep red colour, inclining to purple, with an open crystalline structure. In the process of toughening, the surface of the metal is first covered over with charcoal; a pole, commonly of birch, is then held in the liquid metal in the furnace, which causes considerable ebullition, owing to the evolution of gaseous matter; and this operation of *poling* is continued with the occasional addition of fresh charcoal, until the quality of the assays, which the refiner takes from time to time, attain the required degree of purity indicated by the polished silky appearance of the metal when cut half way through, the light red colour of it when broken, and

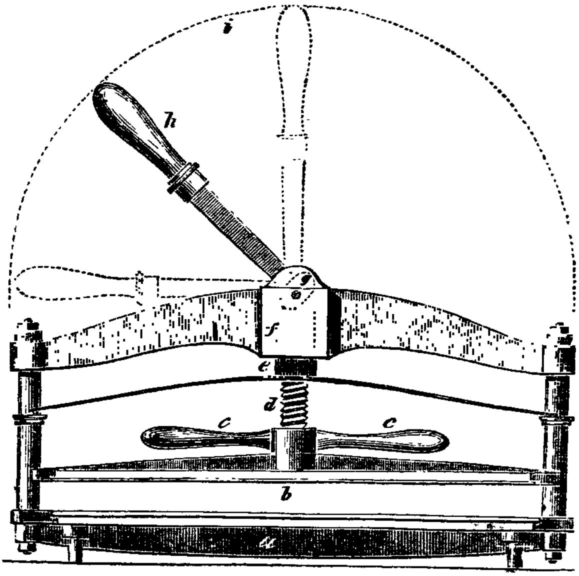
the closeness of the grain. After this a trial of the malleability of the copper is made by taking out a small quantity in a ladle, casting it in a metallic mould, and then hammering it out upon an anvil: if it does not crack at the edges by this operation, it is deemed in a fit state to be withdrawn from the furnace, which is done by lading it out and casting it into rectangular cakes, 12 inches wide by 18 inches long. In preparing copper for the manufacture of brass, it is usual to granulate it by pouring the hot metal through a colander placed over a cistern of *cold* water, which causes the drops of metal to assume by contact with the cold fluid, a ragged appearance, and to which the name of *feathered shot* is given in the trade. For making brass that is to be drawn into wire, the same process as the last is employed, except that the metal is poured into *hot* water; the drops, in consequence, take an oblong form, and are hence termed *bean shot*. In granulating copper, it should be poured into the water by small quantities at a time to prevent explosions. A considerable quantity of copper is exported by the East India Company under the denomination of Japan copper. It is cast in small sticks about six inches long, and weighing about half a pound each. It is of a rich red colour, caused by throwing the cast sticks, as soon as they have become solid in their moulds, into water. Copper unites readily with several of the metals. Its combination with tin is effected at a less heat than is necessary to melt the copper; on which circumstance is grounded the method of tinning copper vessels. For this purpose they are first scraped or scoured, and afterwards rubbed with sal ammoniac. They are then heated (usually over a charcoal fire), and sprinkled with powdered resin, which defends the clean surface of the copper from acquiring the slight film of oxide that would prevent the cohesion of the tin to its surface. The melted tin is then poured into the vessels, and spread about. An extremely small quantity adheres to the copper, which is supposed to be sufficient to prevent the noxious effects of the copper. When tin is melted with copper, it forms the ancient compound termed bronze, the specific gravity of which is remarkable for being greater than would be deduced by computation from the bulks and specific gravities of its component parts. The uses of this hard, sonorous, and durable composition, in the fabrication of cannon, bells, statues, and other articles, are well known. The ancients made cutting instruments of this alloy. A dagger analysed by M. Hielm consisted of $83\frac{7}{8}$ copper, and $16\frac{1}{8}$ tin. Copper unites with bismuth, and forms a reddish white alloy. With arsenic it forms a white brittle compound called tombac; with zinc it forms the important compound called brass; and it is distinguished by various other names, according to the proportions of the two ingredients. It is not easy to unite these two metals in considerable quantities by fusion, because the zinc is volatilized at a heat inferior to that which is required to melt the copper, but they unite very well in the way of cementation. There are various ways of uniting granulated or small pieces of copper with zinc, but the following is the ordinary method adopted in this country. Calamine, which is an ore of zinc, is calcined in a kiln, or made ret hot, then ground to powder, sifted fine, and mixed with ground charcoal, as the calamine is apt to clod and prevent an uniform admixture. About seven pounds of calamine are put into a melting pot of about a gallon content, to which are added about five pounds of the granulated copper; the calamine must be mixed with as much charcoal as will fill the pot, and the copper must lie uppermost. This is let down with tongs into a wind furnace, 8 feet deep, where it remains 11 hours. One furnace usually holds eight pots arranged in a circle round a grate. By the heat the zinc becomes revived, rises in vapour, and combines with the copper, which it converts into brass. Towards the end of the process the heat is suddenly raised, which causes the brass to melt and occupy the lower part of the crucible. After melting it is cast into plates or ingots for use, as it is required. The following method of making brass, mentioned by Cramer, is recommended by the scientific Dr. Ure. The powdered calamine being mixed with an equal quantity of charcoal, and a portion of clay, is to be rammed into a melting vessel, and a quantity of copper, amounting to two-thirds of the weight of calamine, must be placed on the top, and covered with charcoal. By this

method the volatile zinc ascends and converts the copper into brass, which flows into the rammed clay; consequently, if the calamine contain lead, or any other metal, it will not enter into brass, the zinc alone being raised by the heat. Copper unites readily with antimony, a compound of a beautiful violet colour. It does not readily unite with manganese. With tungsten it forms a dark brown spongy alloy, which is somewhat ductile. See ALLOY.

COPPERAS. A name apparently given by persons ignorant of its true nature, to the sulphate of iron, obtained by the decomposition of iron pyrites. The English copperas, or green vitriol, as it is also called, is made from the natural combination of iron with sulphur, known in the various places where they are found, by the several names of copperas stones, horse gold, gold stones, &c. These are collected in great quantities, and laid in heaps about two feet thick, upon a clay floor, surrounded by boards, that direct the rain water that falls upon them to flow into a cistern. The clay floors at some works are 100 feet long, 15 broad at top, but narrowing to 12 at bottom, as they shelve gradually to allow the water to run off easier. The cistern usually contains about 100 tons of water. The copperas stones lie 5 or 6 years before they yield a strong liquor. The sun and rain are found to be the proper agents; and that other water, although prepared by exposure to the sun, and sprinkled on them, only retards the produce. After a time these stones change to a vitriolic earth, which swells and ferments like leavened dough. When a new bed is made, the work is hastened by mixing a good quantity of the old fermented earth with the new stones; and when this has come to perfection, it is refreshed every fourth year by a layer of fresh copperas stones on the top. The copperas water is considered rich if it weigh fourteen-eightieths more than water. The copperas liquor is boiled in leaden vessels, containing about twelve tons. About a cwt. of old iron is put into it at first, and more added as it dissolves, amounting, in one boiling, to about 15 cwt. Fresh water from another boiler is added to supply the loss from evaporation. When the boiling is finished, (which is determined by the deposition of crystals in a little earthen vessel, after a small quantity has been allowed to cool therein,) the liquor is drawn off into a tarras cistern 20 feet long, 5 feet deep, 9 feet over at top, but tapering towards the bottom, where, being left for a fortnight to cool and crystallize, the remaining liquor is drawn off, and is reserved for boiling with new liquor. At the bottom and sides of the cistern or coolers there is usually a crystalline deposit 5 inches thick,—that at the sides being of a bright colour, while that at the bottom is foul and dirty. At some works, instead of putting all the iron into the boiler, a portion of it is added to the liquor in the cistern before boiling. When the pyrites is too abundant in sulphur, and does not alter by exposure to the weather, it is usual to roast it in piles to drive off the superabundance; and when the sulphur is required as a separate product, to distil the pyrites in close vessels. Copperas is also formed by simply exposing some kinds of bituminous earth to air and moisture, from which the crystals are afterwards obtained by washing. The French also manufacture copperas by dissolving old iron in weak sulphuric acid, and crystallizing the solution. Copperas crystallizes in the form of rhomboidal prisms, which are transparent and of a beautiful green colour. Its taste is harsh and styptic; it reddens vegetable blues; two-thirds of cold water, or three-fourths of boiling water, dissolve it. A moderate heat calcines and whitens copperas, by driving off the water of crystallization; a greater heat expels the sulphuric acid. Its constituents, according to Berzelius, are 28.9 acid, 28.3 protoxide, and 43 water; according to Mr. Perret, 1 prime acid, 2 oxide, and 7 water. The chief uses of copperas are the making of ink and in dying.

COPYING PRESS. A machine for speedily producing a fac-simile copy of any manuscript recently written. The method is to place over the letter a sheet of thin damp paper, and subject them both to the action of the press, by which means a portion of the ink is transferred from the manuscript to the damp paper. When letters are intended to be copied by this means, it is usual either to make use of a kind of ink expressly prepared for the purpose, or to add a portion of sugar to the common writing ink. The presses are variously con-

structed; but the screw press, now so common in merchants' counting-houses, is the invention of the celebrated James Watt, who obtained a patent for it about forty years ago. The annexed figure represents an improvement upon this machine, invented by Mr. Ritchie, of Edinburgh. *a* the bed of the press;



b the platten; *c c* handles which revolve on the screw *d*, and are used to draw down the platten on the paper, &c. placed underneath; *e* is a square piece of steel in which the screw works; the square piece slides in a hole of a similar figure on the head of the press, (as shown by the dotted lines at *f*), and on the top of it is a small cam *g*, operated upon by the lever *h*. The ordinary pressure is given, as usual, by the screw; and the cam being subsequently brought down, increases the force almost to infinity through a very small space, and, consequently, by such a press, a person exerting only the usual force can print effectually a larger surface. The other arrangements will be evident upon an inspection of the drawing.

A very simple, and, at the same time, effectual, copying machine may be made as follows: Take a roller of beech, or any hard wood, about 18 inches long, and 1 inch in diameter, and having cut a longitudinal slit therein nearly the whole length, insert in it and fasten very neatly with glue a slip of strong cloth, about 14 inches wide, and 18 inches long; the remaining part of the roller will serve as a handle, and may be cut with several faces to obtain a firmer hold. To use this copying press, lay the sheet of paper on which the letter is written upon the strip of cloth; on that place the thin copying paper, and upon these lay a thick baize, or horse-hair pad; then roll the whole round the roller, and grasping that part where the cloth is with the left hand, turn the roller round with the right, gradually increasing the grasp with the left; the pressure becomes very great, and quite sufficient to transfer the letter to the copying paper.

CORAL, and Coral Fishery. The substance called coral was formerly considered to be of vegetable origin, but it is now admitted to be of animal origin, belonging to the order Zoophytes: by analysis it is found to consist almost wholly of animal matter and carbonate of lime. The coral *plants*, (as

they are termed) sometimes shoot out like trees without leaves in winter; they often spread out a broad surface like a fan, and not uncommonly a large bundling head like a faggot; sometimes they are found to resemble a plant, with leaves and flowers, and often the antlers of a stag, with great exactness and regularity. If, in our researches after the nature of these plants, we should be induced to break off a branch of the coraline substance, and observe it carefully, we shall perceive its whole surface, which is very rugged and irregular, covered with a mucous fluid, and almost in every part studded with little jelly-like drops, which, when closely examined, will be found to be no other than insects of the polypus kind. If a coraline plant be strictly examined whilst growing in the sea, and the animals upon the surface be not disturbed, either by the agitation of the waters or the touch of the observer, the little polypi will then be seen in infinite numbers, each issuing from its cell, and, in some kinds, the head covered with a little shell resembling an umbrella, the arms spread abroad in order to seize its prey, while the hinder part still remains attached to its habitation, whence it never wholly removes. By this time it is perceived that the number of its inhabitants is infinitely greater than was at first suspected; that they are all assiduously employed in the same pursuits; and that they issue from their respective cells, and retire into them at pleasure. The true, or red coral, was considered by Linnæus as an isis, and arranged as such in the *Systema*, though Linnæus himself acknowledged to Mr. Ellis, the author of the *Natural History of Zoophytes*, that the latter had more properly classed it with the *gorgonia*, or sea-fan. The red coral grows in an exposed and somewhat flattened form, with dichotomous branches, that lessen towards their extremities. The flesh is of the colour of red lead, or inclining to vermilion, soft, slippery, and full of minute vessels. The mouths are placed on the surface, and rise up in a conical form, consisting of eight valves, just opening, whence proceed polypi of a white colour, with eight claws, each of which has a double fibre at both edges. The bone, or shell itself, divested of the flesh, is the true coral of the shops, and which, in its natural state, is of a strong texture, and of a bright red colour, with the outside marked with minute furrows, or irregular striations, interspersed with a few slight depressions, corresponding with the situation of the shells before the flesh was removed. The coral fishery is a very lucrative employment. The time for fishing is from April to July; the places are the Persian Gulf, the Red Sea, the coasts of Africa, towards the bastion of France, the isles of Majorca and Corsica, and the coasts of Provence and Catalonia. Spallanzini, in his *Travels in the Two Sicilies*, has particularly described the coral fishery in the Strait of Messina. The instrument by which they force the branches of coral from the rocks, is formed with two poles of wood, crossing each other at right angles, and having a piece of net fastened on the under side to their extremities. A large stone is fixed where the poles are crossed, that the instrument may more readily sink to the bottom. A cord is strongly tied round the middle of it, one end of which the fisherman holds in his hand, guiding by it the net to those places where the coral is supposed to grow, and which is enclosed in the pieces of the net, broken off and drawn up. The rocks which produce the coral are situated almost in the middle of the Strait, at different depths, from 350 to 650 feet. The bottom and caverns of the rocks are the places from which they endeavour to bring up the coral in their nets, and it is a constant observation, that every branch is perpendicular to the plane on which it grows, without ever turning on one side. The coral fishermen have divided the whole track in which they fish into ten parts. Every year they fish in only one of these parts, and do not fish in it again till ten years are elapsed. This interval of ten years they think necessary for the coral to acquire its full growth in height and consistence. When they transgress this law they find the coral smaller and of less consistence; and the intensity of the colour is always in proportion to the number of years they have desisted from fishing.

CORK. The bark of a tree growing wild in the southern parts of Europe, especially in Spain and Portugal. When the tree is about fifteen years of age, it may be barked; and the operation may be repeated for several years, the bark growing again, and its quality improving as the age of the tree increases.

It is chiefly used for forming stoppers for bottles, and floats for fishermen's nets.

CORN. A general name for the various kinds of grain which serve as food for man or other animals; thus wheat, rye, barley, maize, &c., are comprehended under the term corn. In England, however, it is usually understood to signify *wheat;* in America, and most parts of the world, the term implies maize, or Indian corn. Owing to adventitious or natural circumstances, corn is frequently combined with a variety of impurities, denominated smut-ball, dust-brand, pepper-brand, mildew, must, besides a portion that is decayed or partially eaten by insects; there is also frequently a mixture of gravel, earth, and different foreign substances, to a greater or less extent. To free corn from these impurities, numerous machines have been designed, but their effectiveness has proved so limited or partial, as to cause them to be very little employed; and damaged or impure corn, in consequence, possesses a value in the market far below what its intrinsic worth would be considered were there known some simple and cheap process for separating effectually the good from the bad. An apparatus for this purpose was, however, very recently patented, which, in our opinion, is calculated to supply the desideratum in that important branch of art, the experiments already made with it having proved highly satisfactory. We make the following abstract from the specification (leaving out the references to the drawing), which embraces other mechanism and processes immediately connected with the subject under consideration.

Hebert's Patent Scouring, Washing, and Separating Machine. This apparatus "is brought into use whenever the adventitious or impure matter cannot be effectually removed by sifting or other dry operation. The grain to be washed I deposit on a floor in the upper part of a building, and contiguous to a hopper that is fixed to, and passes through a cavity in the floor. Near to this hopper I also collect a heap of very coarse sharp sand (fragments of buhr stones answer well), which has been previously well washed and sifted, so as to detain only those particles which measure from a sixteenth to a thirtieth part of an inch in diameter, and to free it from those which are either coarser or finer. Into the said hopper I then throw a charge for the scouring cylinder (situated underneath it on the next floor); the charge consisting of a mixture of the grain and coarse sand, in the proportion of about five shovelsfull of the grain to one of the sand in its wet state. The length of the scouring cylinder should be proportioned to the magnitude of the operations intended to be conducted by it; but its diameter should not be less than 30 or 36 inches, in order that the pressure of the superincumbent portion upon the lower may cause the sharp angles of the interposed coarse sand to scour off the impurities adhering to the surfaces of the grain. A slow rotation of the cylinder for a few minutes will in general suffice to complete this part of the process; the state of which may at any time be ascertained by drawing out a sample of the grain through a try-hole, made in one of the flat ends of the cylinder, and provided with a stopper. When completed, the door in the cylinder is to be unfastened, and the mixed materials are to be discharged into a large, flat, rectangular sieve, suspended underneath it, and lying submerged in a large body of water contained in a bath. This being done, the cylinder is to be turned half way round upon its axis, so as to bring the open doorway uppermost, and opposite to the short of the hopper above, in order to its being recharged as before; after which the door is to be refastened. From this time, and at every subsequent charge until the work is completed, both the *scouring* cylinder and the *washing* and *separating* bath operate together, the grain in the sieve being agitated by the rotative action of the cylinder in the following manner. On the revolving axis of the cylinder is fixed a pulley, which, by means of an endless corder chain and two guide pulleys (employed to convert the vertical into a horizontal motion), causes a fourth pulley to revolve in a horizontal plane: on the upper side of the last mentioned pulley is a plate, having an eccentric groove, in which a pin fixed to the centre of the bottom of the sieve works; this arrangement, so far, causes the sieve to perform a circular motion in the water; but the sieve is suspended from its four corners to two projecting

arms or levers, fastened to two horizontal spindles (acting as their fulcra), and is, in consequence, made to incline alternately from side to side, in a constantly varying plane, during each revolution of the eccentric plate before mentioned. This compound motion produces a great agitation amongst the particles of corn and sand, causing them to be quickly and thoroughly separated from each other, and the corn to be well washed by the collision. The sand passes through the meshes of the sieve, and is deposited at the bottom of the bath; the bad corn, from its inferior specific gravity, rises to the surface of the water, whence it is floated away by a gentle current over a partition or dam in the bath, into a receptacle on the other side, whence it flows through a spout out of the machine. The current is produced by the constant running into the bath of a small stream of water from a pipe and cock at the opposite end of the bath, and a constant level of water is preserved by its running over the dam. The purified corn alone remaining in the sieve, is now to be discharged thence; for this purpose, two levers fixed to the before-mentioned spindles, and connected by a rod (to cause them to move parallel with each other), are brought into operation; so that upon one of them being pulled, the sieve is lifted out of the water and placed in an inclined position, by which the contents are easily projected into a contiguous hopper, where the corn is allowed to drain during the washing of the succeeding charge of grain, and then it is conducted into the kiln to be dried. See KILN.

CORROSIVE SUBLIMATE. The chloride of mercury; also called the oxymuriate of mercury.

COTTON. The down of the cotton tree or plant, of which naturalists recognise ten varieties. Some of these are to be met with in the warmer parts of Europe; but its cultivation to any extent is chiefly confined to climates within the tropics. The generality of the West India species are annuals, whilst those of Asia are perennial both in branch and root, and rise in a straight line about eight feet high. The cotton down is contained within pods, which, when arrived at maturity, open. The down envelopes a husk called the gin, which contains the seeds of the plant; and the first operation in rendering cotton fit for manufacturing purposes, consists in freeing the down from these seeds. This is effected by first drying it in the sun until the seeds become quite hard; and then operating upon it by a machine called a gin, of which there are two kinds, the one called a roller gin and the other a saw gin. The roller gin is represented in *Fig.* 1. It consists of two small fluted rollers *a b*, about 1 inch in diameter, and 9 inches long, and generally made of hard wood; they are put in motion by the treadle *c* acting upon cranks or

Fig. 1.

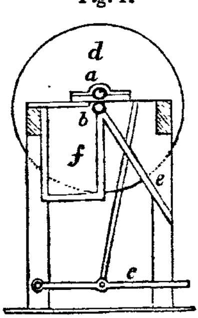
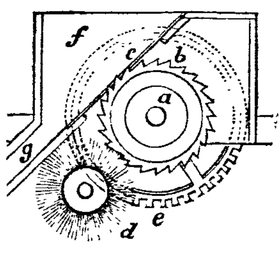


Fig. 2.

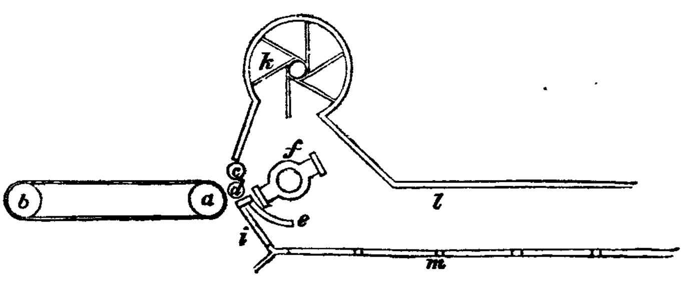


pins in the face of the fly-wheel *d*. The labourer who drives the machine places the cotton on a feeding board, and the cotton is drawn in between the rollers, which being set too close to allow the seeds to pass between them, the cotton falls down the inclined board *e*, and the seeds drop into the box *f*. The saw gin is given in *Fig.* 2. *a* is a roller having a number of circular saws *b* fixed upon it, with a washer of wood between each; *c* is a grating

through which a portion of the teeth of the saws project; *d* is a circular brush driven by the wheel *e* on the axis of *a*, which works into a pinion on the axis of *d*. The cotton being put into the hopper *f*, the teeth of the saws lay hold of the wool and tear it through the grating, whilst the seeds are by that means separated, and roll down the inclined plane of the grating, and finally escape at the spout *g*; the cylindrical brush serves to clear the cotton from the teeth of the saws, and throw it clear of the cylinder, in which state it is ready to be packed for the market.

COTTON SPINNING; the operation by which cotton-wool is formed into yarn. The most ancient and simple method of forming filamentous substances into a continuous thread was undoubtedly by the distaff and spindle, a method still practised by the natives of India, and which appears to be known to every nation removed one step from absolute barbarism. The first improvement upon this simple contrivance was the spinning wheel, invented at a remote and uncertain period; and by means of this machine, with some slight improvements in its construction, the operation of spinning continued to be performed in this country until the latter part of the last century, when an entirely new system was introduced in the art, the process being no longer dependent upon the skill and intelligence of the artisan, but every part of it being performed by mechanical means, with a degree of accuracy and dispatch before unknown. The new system spread with great rapidity, and quickly raised our cotton manufactures, which were previously of small importance, to rank amongst the principal ones of the country. From a paper in the *Repertory of Arts*, it appears that so early as 1730 Mr. John Wyatt, of Birmingham, conceived the idea of spinning by machinery, and that becoming associated with a foreigner named Lewis Paul, a patent was taken out in the name of the latter in 1738. In 1742 a mill was erected at Birmingham, which was turned by two asses. A more successful result attended the exertions of Richard Hargreaves, a weaver in Lancashire, who, in 1767, invented what is called the spinning jenny. In 1769 R. Arkwright invented the method known by the name of water spinning; and in 1779 Crompton combined the principles of jenny spinning and water spinning into a system called mule spinning, and by one or other of these three methods the operation is now performed.

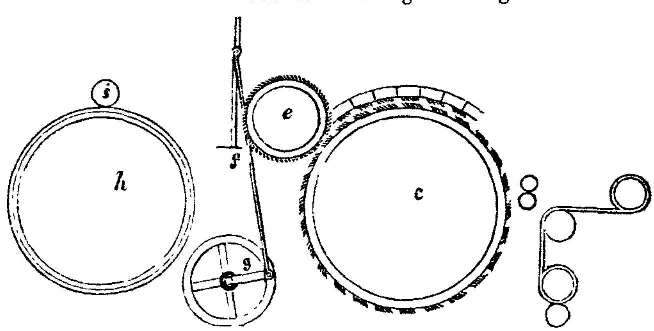
We shall proceed to describe, as briefly as is consistent with perspicuity, each of these methods, taking them in the order in which the inventions stand in point of time; but first, we must note the method by which the cotton wool (which arrives in this country very imperfectly cleaned from seeds, dust, &c.) is freed from these impurities. This operation, which is called *batting*, is performed by a machine called a batter, of which the annexed cut is a diagram.



The cotton is laid upon the endless web, or band, passing round the rollers *a b*, and by this band, which is called the feeding cloth, it is carried to the rollers *c d*, which deliver it upon the curved rack or grating *e*, whilst a scutch *f*, revolving rapidly upon its axis, strikes the cotton with its two edges and divides it, and the gins, sand, &c. fall through the circular grating *e*, and down the inclined grating *i*, at the same time a draft of air, created by the revolution of the fan *k*, blows the cotton forward along the passage *l* into a box, from which

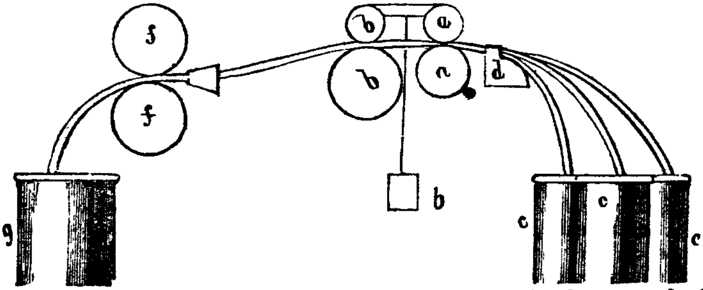
it is from time to time removed, any remaining seeds falling from the cotton through the grating *m*, (which forms the bottom of the passage *l*,) as the cotton is blown along the passage.

We shall now proceed to give a verbal description of the process of jenny spinning, unaccompanied by any representations of the machinery, which being the same as that which, combined with some other machinery, is used in mule spinning, will be described under that head. The process is as follows: The cotton, after batting, is soaped, by being immersed in a strong solution of soap; then pressed in a screw press, and afterwards stove-dried. It is then carded by a carding machine, from which it passes in the form of rolls, about the size of a candle, on to an endless band, from which it is lifted by children, and carried to be roved. The roving is performed on a billy, usually containing thirty-six spindles, driven by bands from a cylinder turned by hand. Upon the side next the carding engine is a feeding cloth, upon which the rolls from the carding engine are united so as to form a number of rolls equal to the number of spindles in the billy. After a certain number of revolutions of the rollers of the feeding cloth, the cloth is stopped, and the rolls being held fast between two clasps of wood, the ends are attached to the spindles, that are mounted on a movable carriage, which, as it recedes, stretches the rolls and reduces them to the proper size of the roving. In returning the carriage, the rovings are built upon the spindles in the form of cones, receiving at the same time a slight twist; and when a sufficient quantity of roving is wound upon the spindles, they are removed to the spinning jenny. The spinning jenny differs from the roving billy in having the clasp boards attached to movable frames or carriages, and the spindles stationary. The clasps, by the receding of the carriage, reduce the rovings to the size for yarn, and during the return of the carriage the yarn is built upon the spindles. Jenny yarn is now little used, except for the weft of calicoes. Water spinning is the name given to Arkwright's method of spinning, because in all the mills in which it was first adopted the machinery was driven by water. The distinguishing feature of this method is the means by which the rovings are gradually reduced in thickness to the size of the intended yarn. In jenny spinning, we have already stated, this is effected by nipping the rovings at one part between wooden clasps, and causing the spindles to which the end of the rovings are attached to recede very gradually; but in water spinning this is effected by passing the rovings between the drawing rollers faster than it is taken in by the feed rollers; the fibrés slide one over the other, and the roving is reduced in thickness, or extended in length, in proportion to the difference of the velocities of the feed rollers and drawing rollers. The process of water spinning is conducted as follows: After batting, the wool is carded by two machines, the first called the breaker, and the second the finisher. The annexed diagram will give some idea of the

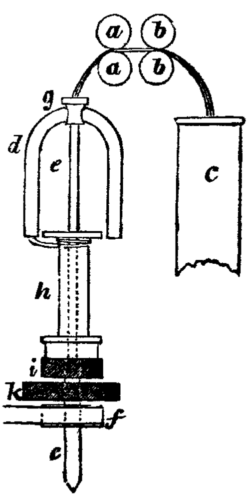


nature of the operation, and of the construction of the machine. The cotton is carried by the feeding cloth *a a* to the feed rollers *b b*, which deliver it on to the carding cylinder *c*. This cylinder is covered with slips of leather, stuck full of bent wires, forming what are called cards, which are ranged parallel to

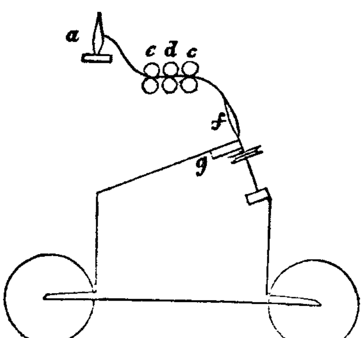
the axis of the cylinder; the arched top *d* of the box in which the cylinder is enclosed is likewise covered with similar cards, the teeth of which incline in an opposite direction; as the cylinder slowly revolves, the cotton is repeatedly torn from it by the top cards, from which it is recovered by the cylinder, until the cotton at length reaches the doffer *e*, which is a cylinder with the cards ranged round it in one continued spiral fillet, that strips the cotton wool from the cylinder in a thin film, which is removed by a steel comb *f*, worked by a crank *g;* and by the comb it is thrown on to a smooth cylinder *h*, called the lapping cylinder; this is surmounted by a light roller *i*, by which the film of wool is pressed flat upon the cylinder, forming what is termed a *lap*. After a certain number of layers are wound upon the lapping cylinder, which is called *plying*, or *doubling*, the machine is stopped, and the lap broken off and removed to the finisher, which has a carding cylinder, doffer, and comb, similar to the breaker; but instead of the wool, as it comes from the comb, passing round a lapping cylinder, it is drawn through a conical vessel by a pair of rollers, which compress it, and deliver it in thin slivers or bands into tin cans; these, when full, are removed to the draw frame, which is represented in the following diagram.



The draw frame contains several heads of rollers, each head composed of a pair of feeding rollers *a a*, and a pair of draw rollers *b b;* the upper roller in each pair is covered with leather, or some other elastic substance, and the lower pair is formed of metal, and fluted. The ends of the slivers contained in the cans *c c* are passed through the leader *d*, and brought under the rollers *a a* and *b b*. If, now, we suppose the rollers *b b* to travel four times as fast as the feed rollers *a a*, or to have a *draught* of four, as it is termed, the slivers will be drawn out to four times their original length. The slivers are united by passing through a conical ring, and conducted by a pair of rollers *f f*, (which do not draw or extend the cotton,) into another can *g;* and if we suppose four ends to be thus united, the sliver will be of the same thickness as the original sliver, but of four times the length. This operation being repeated through several other heads on the same frame, the fibres of the cotton are laid nearly parallel, the sliver becomes more uniform, and is then ready to be carried to the roving frame, in which, besides being reduced, it receives a slight degree of twist. Roving frames have been variously constructed, but the form most approved and in most general use at the present day is what is termed the spindle and flyer roving frame, represented by the annexed diagram. *a a*, *b b*, are draw rollers, between which the sliver is conducted from the cam *c*, and reduced according to the draught of the rollers; *d d* is the flyer fixed upon the top of the spindle *e*, which is put in motion by a band passing over the wheel *f*. The rollers deliver the reduced sliver to the flyers on the top of the



spindles, where it passes through an eye g, and thence proceeds down one of the legs of the flyer (which is made tubular for that purpose,) to the bobbin h, placed loosely on the spindle c, and supported on the rail. The tube of the flyer running swiftly round the bobbin, lays the roving (which thus acquires a twist) on the bobbin as fast as the rollers deliver it; and in order to cover the surface of the bobbin with regularity, the rail i is made to ascend and descend alternately with a slow motion. The bobbin, it will be observed, is dragged round by the flyers, and but for the friction of the surface on which it rests, would move as fast as the flyers; but in this case it would take up no roving, for the quantity taken up will depend upon the difference between the speed of the flyer and the bobbin. A slight degree of friction is then necessary to give the bobbin a slow motion, but as the bobbin becomes full, the weight increases the friction, and consequently would retard the motion still further if it were only dragged round by the flyer; and as it is requisite that the bobbin should always take up the same quantity of roving, its motion is regulated so as to take up the roving exactly as fast as it is delivered from the rollers. The mechanism by which this is accomplished varies in different mills; the following is one of the most approved methods. Two conical barrels are placed opposite each other, the large end of the one fronting the small end of the other. One of these barrels moving uniformly turns the other barrel, by means of an endless strap, which, by being shifted towards either extremity, varies the speed of the other barrel. The belt or strap remains equally tight in every part of the barrels, for the diameter of the one increases in exactly the same proportion as that of the other diminishes. From the second barrel motion is conveyed to pulleys k resting on the bearer or rail i, and having the spindles passing through the centre of each; the bobbins rest on those pulleys, and are carried round with them. The rovings are next carried to the spinning frame. The spinning frame is similar in its operation to the roving frame, except that it has generally three sets of drawing rollers, and from the greater strength which the thread has acquired, no machinery is requisite to regulate its motion; it is therefore dragged round by the flyers. The bobbins, when taken off the spindles filled with water twist for warps, are carried to be reeled. The reel is composed of six rails, in front of which the bobbins are ranged on pins, in a board extending the whole length of the reel. The dimensions of the reel are such as that it requires exactly 1½ yard to go round it; the thread from the bobbins, after passing between several wires, to give a proper degree of tension, is made fast to one of the rails, and the wheel set in motion. After eighty revolutions (one lay) a bell or click strikes, the reel is stopped, and the lays are tied with pieces of thread to keep them distinct. Seven lays form a hank. When the hanks are completed they are taken off the reel, for which purpose one of the rails is hinged, which permits it to be folded inward, and the hank being slided to one end of the reel, the reel is lifted off its bearing, and the hanks are taken off.



It now remains to describe the operation of mule spinning. The preparation is similar to that of water spinning; but previously to the rovings receiving their last reduction on the spinning frame, they undergo a process called stretching. The stretching frame nearly resembling the mule, except in being of larger dimensions: we shall proceed to describe the latter, by means of the annexed diagram. a represents a roving placed in a frame behind the drawing rollers c d e. After passing between the rollers, the reduced roving goes on to the spindle f, which are like those of the common jenny, and have neither bobbins nor flyers. The spindles are placed in a reclining position, and supported on a carriage g. The machine

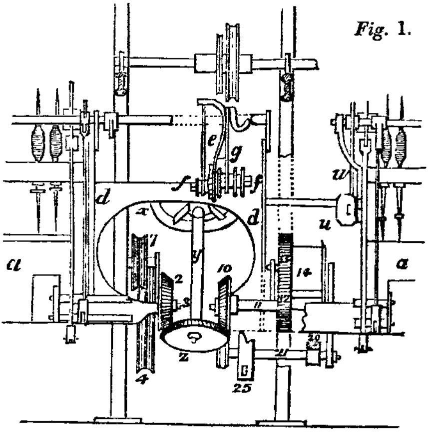
being put in motion, the carriage recedes as fast as the rollers deliver the rovings, the spindles at the same time revolving rapidly, giving sufficient twist to the yard to bear stretching. After the rollers have delivered a certain length (a yard, for example,) of yarn thus imperfectly twisted, they stop, but the carriage continues to recede half a yard further, for example, and the spindles continue to revolve. The yarn is thus stretched, and forms a fair and even thread. In order to save time, the spindles move more rapidly during the process of stretching. The mechanism by which this is effected is called double speed. The yarn being sufficiently hard twisted, the machine disengages itself from the other moving parts of the mule; the attendant then returns the carriage home to the rollers. By this arrangement, comprising the advantages both of the rollers and the spindles, the thread is stretched more gently and equally, and a much finer quality of yarn can therefore be produced. This excellent machine, which has superseded the jenny, and, to a considerable extent, the water frame, and which has carried the cotton manufacture to a perfection it could not otherwise have attained, was invented by Samuel Crompton, a young weaver of respectable character and moderate circumstances, living at Hall-in-the-Wood, near Bolton, and was completed by him in 1779. Being of a retiring and unambitious disposition he took out no patent, and only regretted that public curiosity would not allow him "to enjoy his little invention to himself in his garret," and to earn by his own manual labour, undisturbed, the fruits of his ingenuity and perseverance. The very superior quality of his yarn, it is said, drew persons from all quarters, to ascertain the manner whereby he produced it. He stated to Mr. Bannatyne, that, on the invention of his machine, he obtained 14*s.* per lb. for the spinning and preparation of No. 40, (*i. e.* yarn of forty hanks to the pound); that a short time after he got 25*s.* per lb. for the spinning and preparation of No. 60; and that he then spun a small quantity of No. 80, to show that it was not impossible, as was supposed, to spin yarn of so fine a grist, and for the spinning and preparation of this he got 42*s.* per lb.! These prices were obtained by the unrivalled excellence of the yarn; and it affords a criterion to estimate the value of the machine, when it is found that the price of yarn, No. 100, is at the present day only from 2*s.* 3*d.* to 3*s.* per lb., including the cost of the raw material, which is from 10*d.* to 1*s.* per lb., this surprising reduction having been effected chiefly by the powers of the mule; and notwithstanding it was before supposed to be impossible to spin 80 hanks to the pound, as many as 350 hanks to the pound have since been spun, each hank measuring 840 yards, and forming together a thread 167 miles in length! Although the principle of Crompton's machine was excellent, it was rudely constructed; his rollers were of wood, and all the parts clumsy; for Crompton was unused to tools, and knew but little of mechanics before he attempted to put to practice the beautiful combinations he had conceived. His first machine contained but 20 or 30 spindles. Subsequently, Stones, of Harwich, a machinist, constructed a mule in a workmanlike manner, making the rollers of metal, and applying clock-work to move them; the mule was thus adapted for 100 to 130 spindles. Baker, of Bury, and Hargraves, of Toddington, introduced some improvements. In 1790, Mr. Kelly, of Lanark mills, applied water power to the mule, and shortly after Mr. Wright, of Manchester, constructed a *double mule*. By these successive additions the machine was made capable of working with no less than 400 spindles. Since this period mules have been so much increased in size and effectiveness, that there are many at work in Manchester and elsewhere of 800 spindles each, and some of the prodigious number of 1100 spindles each, or 2200 the pair, the pair being managed by one spinner. Mr. Crompton having made no attempt to secure this important invention, Parliament was memorialized on the subject, and a grant of 5000*l.* was obtained free of all charges; and it is worthy of remark, that at this time (1812), there were at work, on the principle of his invention, between four and five *millions* of spindles! But the course of improvement has not yet stopped; mules are now constructed which do not require the aid of a spinner, the mechanism being so contrived as to roll the spindle carriage out and in at the proper speed, without a hand touching it; and the only manual labour employed

in these machines, (which are called *self-acting mules,*) is that of the children who join the broken threads. The first machine of this nature was invented by the ingenious Mr. W. Strutt, of Derby, son of Mr. Jedediah Strutt, the partner of Arkwright. This appears to have been in the year 1790; and two years afterwards, Mr. Kelly, of Lanark mills, invented another self-acting mule, which is thus described by him in a letter to Mr. Kennedy, which we annex, as it furnishes a very interesting detail of the progress of improvement. "I first applied water power to the common mules in the year 1790; that is, we drove the mules by water, but put them up (that is, the carriage or spindle frame) in the common way, by applying the hand to the fly-wheel, and by placing the wheels (or mules) right and left; the spinner was thereby enabled to spin two mules in place of one. . . . . The mules at that time were generally driven with ropes, made with cotton mill-waste, from a lying shaft in the middle of the room, and over gallows-pulleys above the fly-wheels, on each side of the room. That mode of driving was succeeded by belts, which were in every respect much better, and better adapted to self-acting mules, &c. From the above date I constantly had in view the self-acting mule, and trying to bring it into use; and having got it to do very well for coarse numbers, I took out the patent in the summer of 1792. The object then was to spin with young people, like the water twist. For that purpose it was necessary that the carriage should be put up without the necessity of applying the hand to the fly-wheel. At first we used them completely self-acting in all the motions, the fly continuing to revolve, and after receiving the full quantity of twist, the spindles stood, the guide or faller was turned down on the inside of the spindles, and the points were cleared of the thread at the same instant, by the rising of a guide, or inside faller (if it might be so called). When the outside guide wire, or faller, was moved round, or turned down to a certain point on the inside of the spindles, it then disengaged, or rather allowed a pulley, driven from the back of the belt-pulley, to come into geer, or action, and which gave motion to the spindles, and took in the carriages at the same time (similar to the way you assist the large mules in putting up). But in the above self-acting mule, which performed every motion, after the spindles were stopped it required about three turns of the fly-wheel to move round the faller, and put in action the above-mentioned pulley that took in the carriage, which was a great loss of time. We therefore set aside that part of the apparatus or machinery, and allowed the mule to stop in the common way, on receiving the full complement of twist; and the instant it stopped, the boy or girl, without putting their hand to the fly-wheel, just turned the guide or faller with the hand, which instantly set in motion the spindles, and took in the carriage, the cop being shaped by an inclined plane, or other contrivance. . . . . It may naturally be asked, Why were not the self-acting mules continued in use? At first, you know, the mules were about 144 spindles in size, and when power was applied, the spinner worked two of such; but the size of mules rapidly increased to 300 spindles and upwards, and two such wheels being considered a sufficient task for a man to manage, the idea of saving, by spinning with boys and girls, was thus superseded." So numerous and diversified have been the successive improvements in this important branch of art, that a very large volume might readily be filled with merely a selection of the more ingenious; but our prescribed limits compel us to confine our present notice to the most successful, and we believe the most perfect mechanism for spinning hitherto brought into use, which is the *self-acting mule*, invented by Mr. Roberts, of the firm of Sharp and Roberts, of Manchester. The following description of the invention, extracted from the patentee's specification, we copy from the *London Journal of Arts and Sciences*, Vol. VIII. Second Series.

"The nature of my said invention consists of an improvement or improvements in the mechanism employed to render self-acting the machines commonly known by the names of mule, billy, jenny, jack-frame, stretching frame, and all other machines of that class, whether used to rove, slub, or spin cotton, or other fibrous substances, the particular object of which improvement or improvements is to effect in a more complete manner than has hitherto been done by self-acting machines of the kinds above mentioned, the regular winding

on of the yarn, or roving, upon the spindles, by regulating their rotatory motions according to the gradually varying form and increasing diameter of the cop. In *Figs.* 1 and 2, *a a* is a mule carriage in two parts, one on each side of the headstock, the parts being firmly united by *b b*, a connecting bar of iron, and *c c*, an iron frame; to this is bolted in front a frame of iron *d*, which, at its upper part, is supported by *e*, a spur piece, bolted to the bar *b* and to the frame *d*. On studs in the spur piece are *f f* two ratchet tension barrels; to one of these is fastened *g* a cord, which, after passing over a notch in the spur piece *e*, is wound round and fastened to *h* a drum or barrel; this has also attached to and coiled round it *i* another cord, which after passing over *j* a guide pulley, and a notch in the spur piece, is attached to the other ratchet barrel. A shaft *k*, on which is keyed the drum *h*, has a pinion *l* working into *m* the toothed quadrant, which receives an alternating motion on its centre, through an arc of about 90°, whilst the carriage runs out and in, that is to say, at every stretch. In a groove in the inner arm of the quadrant is *n* a sliding nut moved by *o* a double threaded leading screw, on the lower end of which is keyed *p* a mitre wheel, gearing with *q* another mitre wheel, the central stud of which is opposite to the centre of the quadrant. Attached to the back of mitre wheel *q* is *r*, a pulley, which is turned at intervals by *s* an endless strap passing round it, and *t* a sliding pulley. A weighted lever *u*, called the governor lever, is movable on a stud in the back part of the carriage frame, and forms the upper jaw of a pair of pincers, the lower jaw being *v* a stud in the carriage end. The lever *u*, when not intended to press upon the stud *v*, is carried by an adjustable nut on the lower end of *w*, a rod connected with the arm of the counter faller, and having free play through a hole in a side projection from the arm of the lever. When, in winding on, the tension of the yarn brings the faller wires to nearly the same level, the dropping of the arm of the counter faller allows the lever *u* to descend till it pinches the endless strap *s* against the stud, and drags it along as the carriage runs in, until the rise of the counter faller arm again raises the lever and liberates the strap. The spindles are banded in the ordinary way, and the drums are driven by a band, which, after taking both the grooves in *x*, the driving pulley, is spliced, instead of passing from the carriage to the twist pulley, as in common mules. The pulley *x* is keyed on *y*, an inclined shaft, the upper end of which turns in a swivel collar, and the lower end or foot in an arm of a bell crank. During the process of twisting and backing off, the shaft *y* receives motion through 1, a mitre wheel, which is keyed near its lower extremity, and is driven by 2, another mitre wheel fixed on 3, a shaft, on which is also keyed 4, a double grooved driving pulley, receiving motion by an endless band from 5, the twist pulley above. This pulley band passes under a carrier pulley, and over a double grooved carrier pulley, under the driving pulley 4, again over pulley 7, and under pulley 4, round 8, a sliding carrier pulley, under 9, a carrier pulley, and thence to the twist pulley. The mitre wheel 1, comes occasionally into gear with 10, another mitre wheel, keyed on 11, a shaft, upon which is also keyed 12, a spur wheel, which gears into 13, another spur wheel, firmly connected to 14, a drum or barrel, which is called the winding-on barrel. The diameters of wheels 12 and 13 should be made to give, as nearly as possible, the proper amount of rotation

Fig. 1.



to the spindles, according to their diameters and those of the warves, the final adjustment being made in the diameter of the barrel 14, the whole being adapted to give so much motion to the spindles as will cause them to wind on the whole stretch at the first run in. There is a cord 15, one end of which is

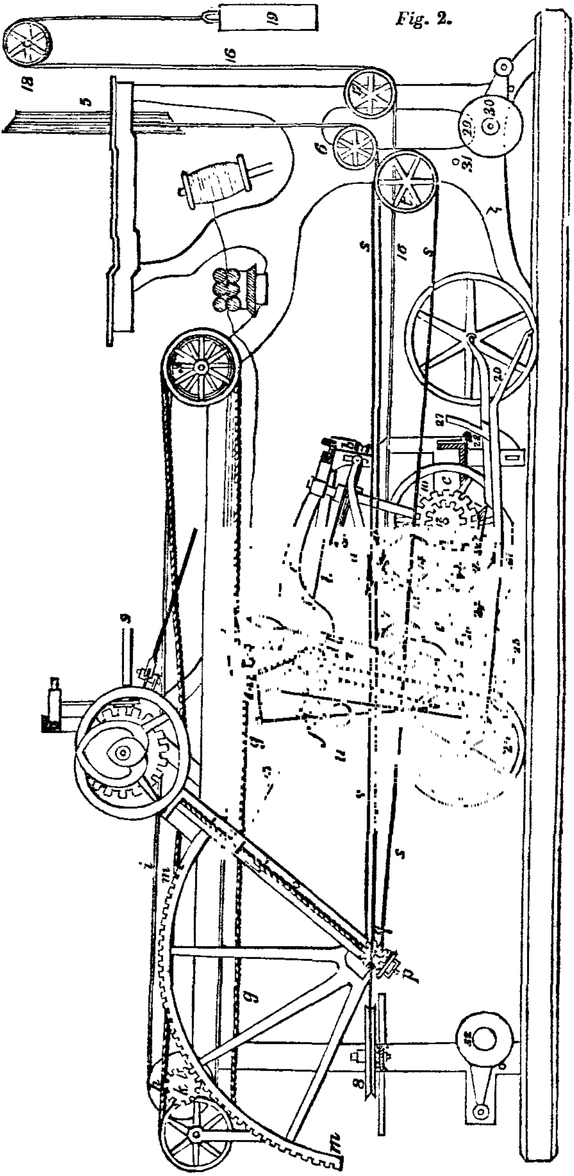
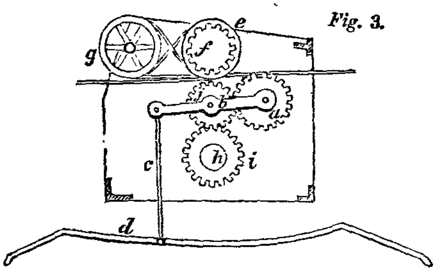


Fig. 2.

tied to the sliding nut *n* in the arm of the quadrant *m*, and the other made fast to the barrel 14, after having made several coils round it; and 16 is an opposing

cord, also coiled round and fastened to the barrel 14, and after passing under 17, a carrier pulley, and over 18, another carrier pulley, it sustains 19, a counterpoise, which causes the barrel 14 to take up the cord 15 as the carriage recedes from the rollers. A lever 20, inclined downwards at both ends, is mounted at its middle upon 21, a tumbler shaft, carrying 22, a fixed vertical arm, which is connected by 23, a link with the side arm of the bell crank; 24 is a stopping bar, movable on a stud in the vertical arm of the tumbler shaft, its lower end passing through and abutting by a shoulder against the upper side of a mortise hole in 25, a stopping piece, which is bolted to the frame *c*; the stopping bar is held against the upper side of the slot by 26, a spiral spring; 27 is a latch on a stud in a projection from the frame *c*, which is pressed by 28, a spring in the direction of a catch on one side of the lever 20; 29 is a radial weight, movable on a stud in the framing, and carrying on a stud near its centre, 30 a friction roller, under which the inner inclined arm of the lever 20 passes, and raises the weight a little just before the carriage completes its run inwards; 31 a stud in the framing, which, by stopping the latch 27 in its motion inwards, disengages the lever 20 at the instant the carriage has completed its run, which allows the weight 29 to depress the inner arm, and so to throw into gear the mitre wheels 1 and 2, preparatory to the recommencement of twisting; 32 is another radial weight, similar to the weight 29, having a friction roller, under which the outer arm of lever 20 comes to raise it, as the carriage reaches its outward limit. When the process of backing off is completed, the mechanism for putting up, or running the carriage in, is put into gear, and simultaneously with it; and by the same, or any other convenient means, the stopping bar 24 is depressed, and the weight 32 depressing the lever 20, shifts the mitre wheel 1 from the wheel 2 into gear with the wheel 10. The diagram, *Fig*. 3, is intended to show the arrangement of the connecting wheels, the winding on barrel, and the crooked lever, when the spindles are driven by bands from a roller, instead of drums, which, as far as the present improvement or improvements in the mule, billy, jenny, jack frame, or stretching frame, are concerned, is almost the only difference in the several machines enumerated; they all being machines of the same class, that is, in which is performed at intervals the winding on of the stretches of yarn or rovings, though used for different purposes, and distinguished by different names.

Fig. 3.



A spur wheel *a* is keyed on the coupling shaft which connects the spindle band rollers on each side of the headstock; *b* is a radial arm centred on the same coupling shaft, and connected by *c*, a link, with *d*, the crooked lever, which is acted upon by the radial weights and catches, as described before; *e* a double grooved pulley, keyed on the same shaft with *f*, a spur wheel; *g* a double grooved carrier pulley, round which and the pulley *e* the twist pulley band is passed twice, as before explained; *h* the winding on drum, keyed on the same shaft as *i*, a spur wheel; *j* a spur wheel carried by the radial arm *b*, and gearing into wheel *f* whilst the twist is being given, and into wheel *i* during the winding on. In the adaptation of the present improvements to the mule, billy, jenny, jack frame, or stretching frame, according to the diameter of the cop to be formed, or the length of stretch made in the several machines, it may be requisite to vary the length of the grooved arm of the quadrant. Whilst the carriage is running in, it turns by the band *g*, *Fig* 2, the drum *h*, its shaft *k*, and the pinion *l*, which works into the quadrant *m*. When the quadrant begins to move, its grooved arm stands about 12° beyond the vertical position from the rollers, and during its action it turns on its centre inwards, through an arc of about 90°. At the commencement of a set of cops,

the stud in the nut *n*, to which the cord 15 is attached, is set opposite, or nearly so, to the centre of the quadrant, in which position it suffers no change of place by the motion of the quadrant. As the carriage recedes from the point of attachment of cord 15, it causes the rotation of the winding on drum 14, round which the cord is coiled, and the drum through the train of wheels 13, 12, 10, and 1, that of the pulley *x*, which, by the spindle drums, gives motion to the spindles (see *Fig.* 1.) The rotation of the spindles during the first run-in of the carriage, just suffices to wind on the stretch of yarn upon the bare spindles. As the diameter of the cop increases by each succeeding layer, fewer revolutions will be requisite to effect the winding on of the constant length; and, therefore, the whole quantity of motion imparted to the spindles during a run-in must undergo progressive diminution so long as the diameter of the cop is increasing, which goes on until the bottom is formed. This decrease of motion in the spindles is obtained by lessening the quantity of cord to be uncoiled from the winding-on barrel; an effect which results from the advance of the nut *n* along the arm of the quadrant, the amount of the effect being exactly commensurate with this advance, as is apparent when the grooved arm of the quadrant, at the end of the run-in, nearly coincides with the line of traction of the cord 15. The motion which slides the nut along the quadrant arm is produced in this way. During the process of backing off, the spiral coils of yarn are unwound from the ends of the spindles, and the faller is depressed when the counter faller by its weight rises, and takes up the uncoiled or slack yarn, and thus the faller wires keep up the tension as the yarn is uncoiling. Whilst the carriage is running in, the spindles, in winding on the stretch of yarn, take up by degrees the coil yarn also; and as this is effected, the faller wires are brought to nearly the same level. At the first run-in, this approach of the faller wires takes place only as the carriage comes up to the rollers. The power of winding on increasing as the diameter of the cop enlarges in the subsequent stretches, the coil yarn gets taken up before the carriage has run home; and when this occurs, the descent of the counter faller allows the governor lever *u* to fall, and to pinch the endless strap *s* against the stud *v*. With the motion of the carriage the strap is dragged along, and turns the leading screw *o*, which slides the nut *n* towards the circumference of the quadrant. The strap continues to be dragged until the retardation of the taking up, from the diminished velocity of the spindles thus produced, permits the counter faller again to rise and relieve the strap from the pinch of the lever. In this way the nut *n* is made to advance upon the quadrant arm, in proportion as the expanding diameter of the cop accelerates the action of winding on, and a correspondent abatement in the whole number of revolutions of the spindles is the result. As soon as the cop has attained its full diameter, that is, when the bottom is formed, the winding on power then remaining uniform, the governor lever is no longer made to act upon the strap, and, consequently, the nut *n* travels no farther from the centre of the quadrant during the completion of the cop. Besides the adjustment of the whole amount of winding on motion, each stretch is adjusted to the growing diameter of the cop, which is effected by causing the point of attachment of t' › drag cord 15 to advance progressively upon the rim of the barrel 14. The g ›ved arm of the quadrant, by carrying the point of attachment of the cord 15, after the first stretch through an arc of about 90° at each run-in, causes the cord to be uncoiled from the barrel 14, by a ratio increasing as the carriage recedes from the quadrant; and this variable rotation of the barrel is increased by the successive shifts of the nut *n* from the centre of the quadrant, thus adapting the rotation of the spindles to the winding-on powers of the cop, through its various diameters from the base to the summit of the cone. Having now described my improved mechanism for adapting the rotation of the spindles to the regular taking up of the yarn or roving, as the form and diameter of the cop changes throughout the operation of winding on, I do hereby declare, that my invention consists in the method or means to be employed for that purpose hereinbefore described. The mechanism thus employed by me affects the rotation of the spindle in two ways; first, rotatory motion is given to a drum or barrel, which turns the spindles whilst the carriage is running in by uncoiling

from it a portion of a cord, strap, or chain, attached to the drum, and having its other extremity fastened at some point in a radial arm which describes an arc, whilst the winding-on drum is receding from the point of attachment of the cord in a right line. This compound motion adjusts the rotation of the spindles to the varying power of taking up by the conical cop as the yarn or roving is being coiled on its different diameters, during the winding on of each stretch. Secondly, during the progress of the formation of a cop, the situation of the point of attachment of the uncoiled end of the cord, strap, or chain, on the radial arm, is changed progressively, as the increasing bulk of the cop demands fewer revolutions of the spindles to take up the stretch, and, consequently, there is a shorter length of the cord to be uncoiled from the barrel." We refer the reader to the articles SPINNING and WEAVING for further information on this important branch of art, as cotton is not the only fibrous matter to which such mechanism is applicable. It is a remarkable circumstance in the cotton manufacture, and highly honourable to British skill, that all its numerous and varied operations are performed by machinery. Mr. Baines, in his valuable *History of the Cotton Manufacture*, justly observes, "It is by iron fingers, teeth, and wheels, moving with exhaustless energy and devouring speed, that the cotton is opened, cleaned, spread, carded, drawn, roved, spun, wound, warped, dressed, and woven. The various machines are proportioned to each other in regard to their capability of work, and they are so placed in the mill as to allow the material to be carried from stage to stage with the least possible loss of time. All are moving at once, the operations chasing each other; and all derive their motion from the mighty engine, which, firmly seated in the lower part of the building, and constantly fed with water and fuel, toils through the day with the strength of perhaps a hundred horses. Men, in the meanwhile, have merely to attend on this wonderful series of mechanism, to supply it with work, to oil its joints, and to check its slight and infrequent irregularities; each workman performing, or rather superintending, as much work as could have been done by two or three hundred men sixty years ago. At the approach of darkness, the building is illuminated by jets of flame, whose brilliance mimics the light of day, the produce of an invisible vapour generated on the spot. When it is remembered that these inventions have been made within the last seventy years, it must be acknowledged that the cotton mill presents the most striking example of the dominion obtained by human science over the powers of nature, of which modern times can boast."

COULTER. A stout iron knife or blade fixed to the beam of ploughs, which serves to cut out the furrows.

COUNTERBALANCE. A weight applied to balance the vibrating parts of machinery upon their axes, so as to cause them to turn freely, and to require little power to put them in motion; also a weight by which a lever acted upon by an intermitting force is returned to its position, as in the case of the beam of a single acting steam engine.

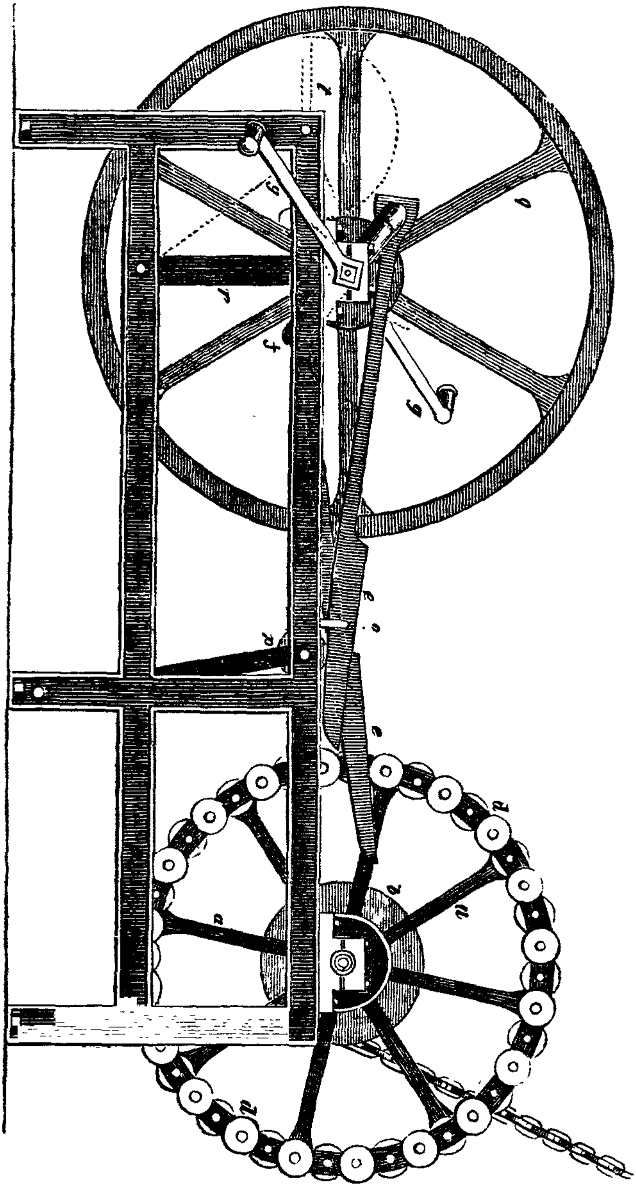
COUPLING BOX. A mode of permanently connecting two shafts: they are variously constructed, the most common being simply a tube embracing the end of each shaft, with a pin or bolt passed through each.

CRAB. A kind of small capstan, consisting of an upright shaft, having several holes at the top, through which long bars or levers are thrust. The name of crab is likewise given to a simple portable crane, on the wheel-and-axle principle, and chiefly used for raising building materials to the tops of houses, &c. There is a machine, likewise called a crab, that is used in launching ships, or heaving them off or on to their ways or slips.

CRADLE is a name given to a supporting frame of timbers, which is placed under the bottom of a ship, in order to conduct her steadily into the water when she is to be launched, at which time it supports her weight while she slides down the inclined plane or slip, which is for this purpose smeared with soap. The bedsteads for wounded seamen are also called cradles; these, as well as those used for rocking children, require no particular description.

CRAMP. A portable kind of iron press, chiefly designed and employed for closely compressing the joints of frame-work. See FLOORING CRAMP.

CRANE. A machine employed at wharfs, warehouses, &c. for raising and lowering goods; it consists of a long projecting arm, called the *jib*, having a pulley at the outer end, over which passes the rope or chain by which the goods



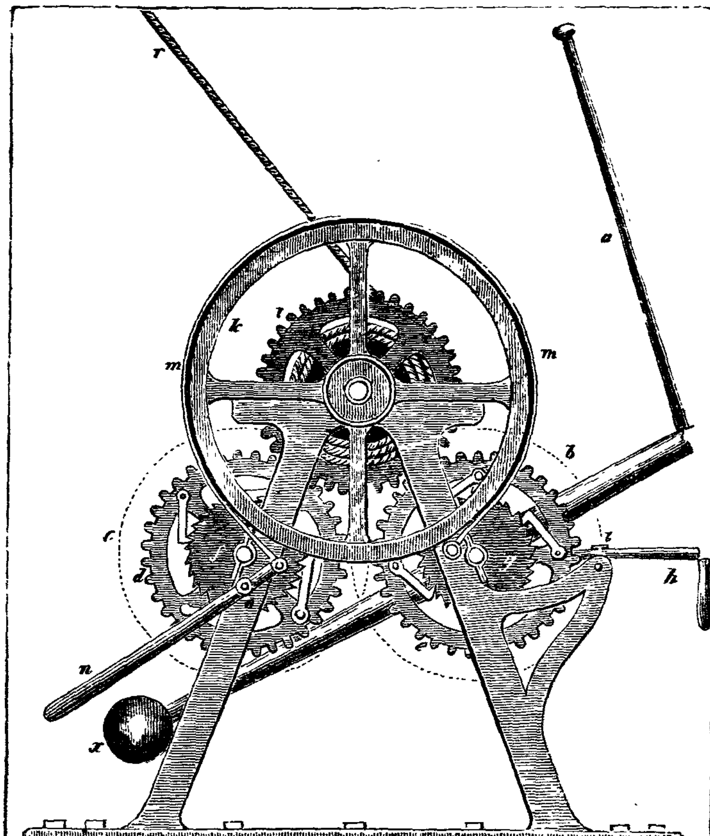
are raised, the other end of the rope being wound round a barrel either attached to the foot of the jib, or placed at any convenient distance from it. Various modes have been resorted to for turning the chain barrel; on piers and jetties

it is frequently placed erect, and worked like a capstan: another method which was formerly very common, but is now little used, was to place it horizontally, and connect it with the axis of a large hollow drum, within which were placed a number of men, who, by stepping upon battens nailed upon the interior circumference parallel to the axis, caused the drum to revolve. But the most effective and best mode of employing the strength of men in working cranes (in situations which will admit of its application), is that invented and patented by Mr. Hardy: as in the preceding plan, the chain barrel is connected with a large drum fixed upon a horizontal axis, but the steps upon which the labourers tread are ranged upon the outside (instead of the inside) of the drum, radiating like the floats of an undershot water-wheel, and the labourers continually step upon that arm or step which is horizontal, so as always to act upon the longest lever. One or more of these cranes were erected at the East India Warehouses, and the principle has been since rendered familiar to one very numerous portion of the public by the invention ascribed to Mr. Cubitt, of Ipswich,—called the treadmill.

The preceding figure represents a side elevation of Mr. L. Wright's patent crane, erected at the West India Docks, and which was the subject of much acrimonious controversy amongst some of the scientific periodicals of the time. *a* is the principal wheel, fixed to and revolving with the chain barrel *b* on the axis *c;* the periphery of the wheel *c* is made perfectly flat on both sides, for the reception of the numerous small wheels *d,* alternately placed on the opposite sides of the ring, with their axes fixed into it; these, which may be called friction wheels, are solid, about an inch thick, and five inches in diameter—they are turned smooth, and made bright in all parts; *e e* are two (of four) levers, worked by a four-throw crank *f f* turned by the winches *g g;* the levers pass between guides at *o,* and slide over rollers at *p,* which form the fulcrum of the levers; and by the revolutions of the cranks the levers are successively projected against the under sides of the small wheels *d,* from whence they are, by the continued revolution of the cranks, again withdrawn, and again projected under the next little wheel below the former, each wheel being raised by the angular motion of the lever over which it rolls. It should be observed that only one side or half of the machine is seen, the other side being a duplicate of it, having two similar levers, large wheel, and smaller wheels, &c. The machine (as delineated) is in gear; to put it out of gear a locking bar *t* is lifted, and thrown into the position shown by the dotted lines; then the framing *r* which carries the crank, inclined planes, and fly-wheel, and turns upon the centre *s,* is thrown back, by which the axis of the crank moves in the arc of a circle (shown by dots) to the position *n.* What mechanical advantage the inventor expected to obtain by this singular construction, it is hard to say; the machine is cumbersome and unsightly, has a complication of parts, in which the friction far exceeds that of a well-made crane of the common construction, to which it is also decidedly inferior in the circumstance of affording no means of altering the power or velocity according to the weight to be raised. The method adopted by the inventor for putting the machine in and out of gear is also very defective; but if the crane offered any advantages in other respects, this latter defect might be obviated.

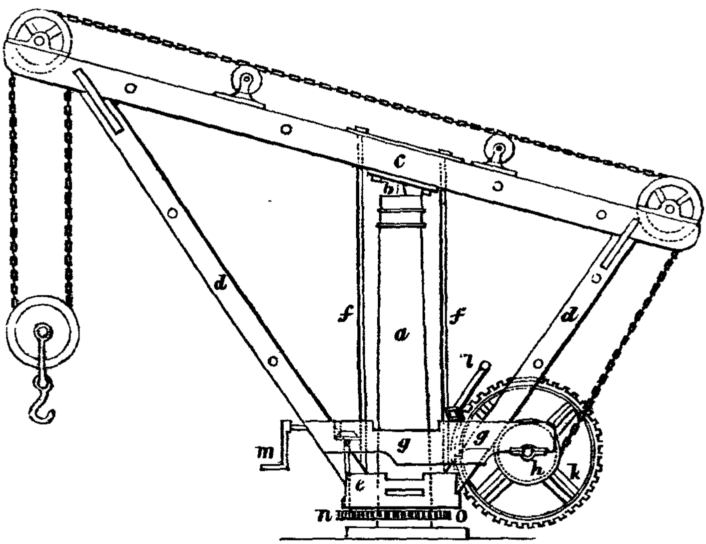
In Mr. Revis's patent crane, which we are about to describe, the alternating motion of a single lever is employed to produce rotatory motion by means of a well-known mechanical arrangement, instead of producing such motion by turning a winch. The engraving on the succeeding page represents an elevation of this machine. *a* is the alternating lever (shown as broken into two parts for want of space), and having a counterbalance at *x;* it is on the opposite side of the machine to that represented, and its fulcrum being the axis of the toothed wheel *b,* which gears into another toothed wheel *c,* motion is given to both wheels in opposite directions. These two wheels are shown merely by two dotted circles, to avoid confusion in the drawing. On the axis of the wheels *b* and *c* are placed the wheels *d* and *e,* which are not fixed to the axles, but turn loosely upon them; each of these wheels carry four palls or clicks, which fall into the notches of two ratchet wheels *f* and *g* that are fixed to the axis on which *d* and

e turn *loosely*. The operation of the lever, therefore, which causes the two first mentioned wheels *b* and *c* to revolve in opposite directions, produces precisely the same effect upon the ratchet wheels *f g*. It will now be observed that the ratchet teeth and palls of both wheels incline, in respect to each other, in the same direction; and as the ratchets are turned round in opposite directions, the palls in one wheel slip over the ratchet teeth, while in the other wheel the palls catch into the ratchet; the latter is thereby locked to the toothed wheel, which now operates upon the toothed wheel *l* on the working barrel, upon which the rope or chain *r* is wound. During this process, the other wheel and ratchet (which we will suppose to be *d f*) has no effect, from their not being connected;



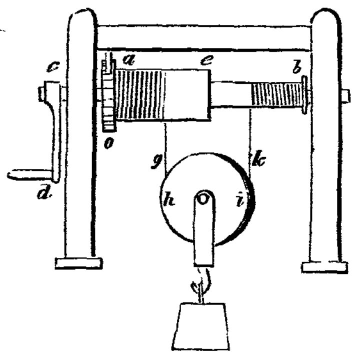
but upon reversing the motion of the lever, these become fastened together, while the former are simultaneously loosened; and as the wheel *d* revolves in an opposite direction to *e*, the wheel *l* is turned round in the same direction as previously, and the rope or chain on the barrel proceeds in an uniform course. Having thus explained the manner in which the motion of the lever *a* is communicated to the other wheels *b c*, and thence to the rest of the machine, it is obvious that the putting of the wheel *b* out of gear with the wheel *c*, will stop the forward action of the crane; this is effected by means of the lever *h*, which turns horizontally upon a fulcrum pin at *i*, and slides the axis in its bearings, so that the wheels *w* and *c* are placed out of contact with each other.

This is done when it is intended to lower the rope or chain; but if a weight or goods be appended to it, the friction band *m m* is made to press against the periphery of the fly-wheel *k* by raising the lever *n*, which, having its fulcrum at *o*, draws the friction band tightly over the fly-wheel, and the goods are thus lowered with safety and expedition. But, for general purposes, the wheel and pinion turned by a winch is superior to all other modes of working cranes, and more particularly is it superior to any arrangement of reciprocating levers, as it produces a smooth continuous circular motion, avoids the jerks and concussions attending the latter, and saves a vast deal of friction, complexity, and expense; accordingly, we find the wheel and pinion now generally adopted almost to the exclusion of every other method. We have already stated that the barrel is sometimes attached to the jib so as to turn with it. The annexed engraving represents an excellent construction of a crane of this description, several of which are erected upon the wharfs of the Regent's Canal. *a* is an upright pillar of cast iron firmly fixed in a foundation of masonry; *b* a pin in

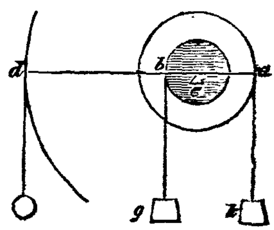


the head of *a*, which supports the jib *c*, and forms the pivot round which it turns; *d d* two struts, supporting the extremities of the jib, and the lower ends resting on a collar *e* encircling the lower part of the pillar, which collar is suspended from the jib by the iron rods *f f*; *g* is one of the side frames supporting the barrel *h*; *k* a toothed wheel on the axis of the barrel, and turned by a pinion, on the axis of which is fixed the winch *l*. The crane is turned round upon its pivot by means of the winch *m*, which, by means of an intermediate wheel and pinion, turns the pinion *n*, working in the wheel *o*, fixed to the base of the pillar *a*.

The following figure represents a modification of the wheel and axle, known by the name of the "Chinese Crane," which, for simplicity of construction and immense power, far surpasses any other machine which is applied to purposes for which this is adapted; and however its modest and unassuming appearance may prevent its admission into the elegant companies of wheels and pinions, which we see associated together in this age of mechanical combination, there can be little doubt that it will eventually work its way into notice by its own merits, to the displacement of some of those complicated arrangements of wood, iron, and brass, which, in some cases, seem to be erected for no other purpose than for employing a horse to do the work of a man. The construction

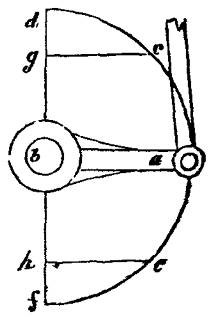


of this machine will be readily understood by reference to the figure. *a b* is a windlass, which is worked by a winch or handle *c d*. It will be seen that the windlass *a b* partakes of two diameters, that part from *a* to *e* being larger than the remaining part *e b*; the cord *g* is wound round the part *a e* of the windlass, and is passed under the movable pulley *h i*, and carried over the part *e b* of the windlass, on the opposite side to that from which it descended at *a e*; the weight to be raised is suspended from the pulley *h i*. Now if a power be applied at *d*, and the windlass be caused to make one revolution, a portion of the cord *g* equal to the circumference of the part *a e* of the windlass, will have been wound on to the windlass; but the part *e b* of the windlass has also made one revolution, consequently a portion of the cord, equal to the circumference of *e b*, has descended, so that after one revolution the cord will have been shortened a quantity equal to the difference between the larger and smaller barrel of the windlass; but as this difference has been divided between the two parts of the cord *g* and *k*, it follows that the weight has been raised through a space equal to only half the difference of the circumferences *a e* and *e b*. But as circles are to each other as their radii, the following simple rule may be deduced for calculating the power of these machines; as *c d*, the radius of the winch, is to half the difference of the radii of the parts of the windlass *a e* and *e b*, so is the weight *w* to the power which is necessary to produce an equilibrium. For example, put $c\ d=18$, the radius $a\ e=6$, and the radius $e\ b=3$; and suspend a weight of 108 lbs. from *h i*; we then have $6-3\div 2=1\frac{1}{2}$, and as $18 : 1\frac{1}{2} :: 108 : 9$; consequently a power of 9 applied at the point *d* would be equivalent to a weight of 108 lbs. acting upon the pulley *h i*. This subject may perhaps be better understood by referring to the annexed diagram, where *a e* represents the radius of the larger part of the windlass, and *b* the smaller radius, *e d* being the radius of the winch; and we may suppose *d a* to represent a lever, whose fulcrum is *e*; and as each of the ropes *g k* bear equal parts of the weight of 108 lbs. we represent the whole weight by two distinct weights *g* and *k* acting upon the points *b* and *a* of the lever *d a*; and if we retain the proportions $d e=18$, $a e=16$, and $b\ e=3$, we have a weight *k* on one side of the fulcrum, at the distance of *b*, whose quantity is 54; and we have a power of 54 acting on the opposite side of the fulcrum, at the distance of 3. Now it will easily be seen from the principles of the lever, that *g* will sustain a quantity equal to $\frac{1}{2}$ *k*, consequently there will remain a weight of 27 acting at *a*, to be kept in equilibrio by a force applied at *d*; but *e d* is 3 times *e a*, therefore a power equal to 9 applied at *d* would balance a weight of 27 acting at *a*; which is precisely the same result as was obtained by the rule before laid down.



CRANK. A short arm or lever fixed to a shaft in any machine, and set in motion by a connecting rod proceeding from some other part of the machine, which has a reciprocating motion to and fro. To obtain a continuous rotatory motion of the crank and shaft it is necessary to fix upon the shaft a fly-wheel of considerably larger radius than the crank,—for when the connecting rod lies in the same direction or right line as the crank, and no longer forms any angle with it, it can have no tendency to move the crank to either side; but the heavy fly-wheel, which, from its greater radius, has travelled much faster than the

crank, has acquired a considerable momentum, which urges round the crank when the connecting rod has ceased to impel it, or carries the crank past the dead points, as it is called. Although this means of obtaining a rotatory motion had long been in practice in various machines, as in the turning-lathe, and knife-grinder's wheel, yet it is a singular fact that a considerable time elapsed after the invention of the steam engine ere the same simple and effective method was employed to obtain a rotatory movement from the reciprocating action of the engine beam, whilst several schemes, exhibiting much contrivance and ingenuity, but which were inadequate to the object in view, were from time to time proposed. By the addition of the crank and fly-wheel to the steam engine, the latter, which before was chiefly used for pumping water, has become generally applicable as a prime mover of machinery, and its utility has, in consequence, been augmented a thousand fold. But the utility of the crank and fly-wheel, as applicable to a steam engine, consists not merely in converting rectilinear into circular motion, but also in gradually destroying the momentum of the piston, and bringing it gently to a state of rest at the end of each stroke. It is a law of nature that all bodies have a natural tendency to preserve their state of motion or of rest, until opposed by some external force. This property of matter occasions a great loss of power in the steam engine, where a massive beam, with all its appendages, have to be reversed at each stroke of the engine; and were it suddenly stopped and reversed when at its greatest velocity, the shock would be so great as speedily to destroy the machinery. The loss of power employed in overcoming the *vis inertiæ* of the beam cannot be avoided, but the shock at the reversal of the motion is prevented by means of the crank, in a manner which will be best explained by the diagram in the margin. Let *a b* represent the crank of a steam engine, equal to half the length of the stroke, or half *d f*, and let *d c a c f* represent the semicircle through which the crank travels whilst the piston performs a stroke, or moves through the space *d f*. Now, when the crank is in its present position, the piston is at its greatest speed, and travels with nearly the same velocity as the crank, moving through the space *b g* whilst the crank passes from *a* to *c*. But when the crank moves through the next portion of its revolution *c d*, equal to the former portion *a c*, the piston only moves through a space equal to *g d* in the same time as it before moved through the space *b g*, which is nearly double *g d*: hence it is seen that the crank, by diminishing the speed, is admirably adapted for preventing the shock which would be experienced from too sudden a reversal of the motion. A want of a thorough comprehension of the mode in which the fly-wheel and crank operate, has been the origin of many attempts to supersede them. Of these we shall only notice the following, which is the invention of Mr. J. Apsey.



At *Fig.* 1, page 421, is an elevation of the apparatus; *a a* is a strong elliptical frame of cast iron, having fixed on each side a toothed rack *b c*. This frame is supposed to be immediately connected to the piston rod of a steam engine or other rectilineal moving force, the motion of which causes the toothed wheels *d* and *e* (the wheel *e* is behind *d*, as is shown in the edge view of them at *Fig.* 2,) to revolve on the axis *i*, which axis communicates its motion and force to whatever machinery may be connected to it. *f g* are two guide bars, and *h j* are two guide rings or annular plates, in front of the wheels *d* and *e*, which serve to keep their respective parts in their proper places. It will be observed that the frame *a a* is represented at the lowest point of its descent · during such descent it turns round the wheel *d* by means of the rack *g*, and at the same time causes a revolution of the axis; by the ascent of the frame the wheel *d* revolves the contrary way, but it then runs freely upon the axis, so as to have no influence upon it; during the same time the opposite wheel *e* becomes locked to the axis, and by means of the rack causes the axis to continue revolving in the direction given to it by the previous operation of the wheel *d*, as will be best understood

by an explanation of *Fig.* 2, which exhibits the toothed wheels and axis distinct from the frame and side racks. To each of the wheels *d* and *e* are fixed the guide rings *h j*, and a clutch box *k l*, which turn with the wheels on a smooth part of the axis, as shown at *i* in the separate *Fig.* 3. These wheels are alternately connected to the axis, to give it motion, by means of the clutches *o p*, which have merely a sliding motion along the axis, and are constantly pressed against the boxes *k l* by means of helical springs *q r* wound upon the axis, and confined in a case, as represented in the figure. The clutches *o p* have grooves made in them, as shown by the end views of them given in the separate

Fig. 1.

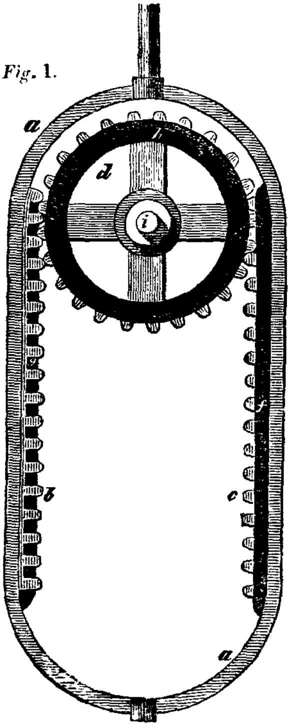


Fig. 2.

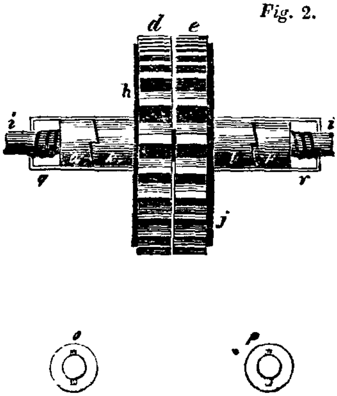


Fig. 3.

figure *o p*, through which the stuts *s t*, *Fig.* 3, slide, and secure them to turn round with the axis. As the action of the apparatus may not be quite clear to some of our readers by the foregoing, we will just repeat that the raising of the elliptical frame containing the side racks, causes the wheel *e* to operate upon the axis by its becoming locked to it by the agency of the clutch *p*; but on the motion of the frame being reversed, by the reciprocating action of the piston rod, or other rectilineal moving force, the wheel *e* is released from the axis, and the other wheel *d* becomes locked to it by the agency of the clutch *o*, which carries the axis round in the direction previously given to it, and by the repetition of the alternations of the frame, the axis is caused to revolve continually in the same direction. Motion is often required to be communicated to machinery at a distance from the first mover, and this is usually effected by a metallic shaft, which, if the distance between the machinery and the first mover be great, must be made of considerable thickness, to prevent its being twisted to pieces by the power applied, or else by chains, straps, or ropes, which, to prevent their slipping on the drums or pulleys over which they pass, causes considerable impediment to the motion by friction. These are inconveniences which cannot

in all cases be avoided; but under some circumstances the following method of transmitting motion through the medium of three rods and two triple cranks, connecting the machinery with the first mover, might be introduced with considerable advantage. The apparatus is represented with the axes of motion placed horizontally by *Fig.* 1, and with the axes placed vertically by *Fig.* 2. The same letters represent similar parts in both figures. It will be perceived that the motion may be in the direction shown by the arrows, or the contrary; and hence it may be reversed at pleasure. The triple crank *a b c*, to be put in rotation by any first mover, is connected by three rods to a similar

Fig. 1.

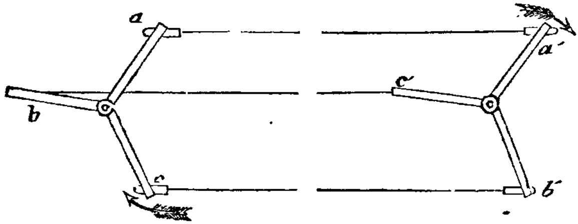
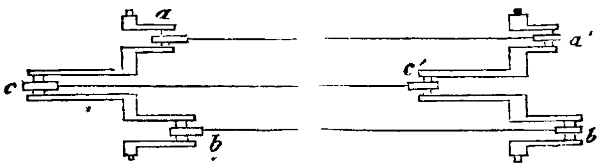


Fig. 2.



crank *a′ b′ c′* of equal dimensions; and as the cranks project from the axes at equal distances, there will always be one of them in a position to produce a pulling action, and hence there will be no necessity for having the conducting rods stronger than what may be sufficient to sustain, by tension, the resistance of the machine to be put in motion, and thus the expense of transmitting motion by this method to a considerable distance will be very small. The motion, too, will be perfectly uniform; for as the leverage of the crank *a*, for instance, diminishes by its rotation, that of the corresponding crank *a* will be equally diminished; so that whatever motion is produced by the first mover will be faithfully transferred to the machinery.

CRAPE. A light kind of stuff, somewhat like gauze, much used in mourning. It is made of raw silk, jammed and twisted in the mill, and woven without crossing. Crapes are either crisped or smooth; the first double, expressing a closer mourning; the latter single, used for denoting a less portion of grief. The silk destined for the first is more twisted than that for the second; it being the greater or less degree of twisting, especially of the warp, which produces the crisping given to it: when taken out of the loom, it is steeped in clear water, and rubbed with a piece of wax for that purpose. Crapes are all dyed raw.

CRAYON is a general name given to various mineral and vegetable substances used in designing or painting in pastil, whether they have been beaten and reduced to a paste, or are used in their primitive consistence, after sawing or cutting them into long narrow slips. In this last manner red crayons are made from red chalk; white, from white chalk; black, from charcoal and black lead. Crayons of all other colours are compositions of earths reduced to paste. The tempering of crayons is found to be an operation of great nicety, to avoid their being so hard as to impart an insufficient supply of colour; or, on

the contrary, so soft as to crumble away, and to be little better than a powder upon the paper. A variety of slightly glutinous fluids have been proposed to give them the due degree of coherence; but the strength and the kind of fluid used requires to be varied according to the nature of the colour to be employed. The English manufacturers employ a variety of substances for this purpose; among which may be mentioned ale-wort, rendered glutinous by boiling, and gum tragacanth. It is obvious that the marks made upon paper by such compositions as we have mentioned, can be but slightly attached to the paper, and that they are extremely liable to be injured or defaced. Various means have been resorted to for fixing them in such a manner, that, without having their tints injured, they may be enabled to bear rubbing. When the picture is made on unsized paper, Cathery recommends the back to be brushed over with a size made of half an ounce of isinglass, and two drachms of powdered alum, boiled for a quarter of an hour in a quart of water, and strained. This size, used milk-warm, penetrates the paper, and effectually fixes the picture. He also recommends another way, which is applicable to large drawings done on sized paper; it consists in sponging with the glutinous fluid a piece of unsized or blotting paper, of the same size as the picture. This wetted paper being laid flat upon a table, the face of the picture is pressed upon it in every part. The chalk thus becoming wet with size adheres to the original surface, and, by taking care wholly to avoid the smallest sidewise motion whilst the two surfaces are in contact, the colours are not in the least daubed, nor is the minute quantity of colour transferred to the blotting paper any injury to the piece. Sebastian Grandi, an Italian artist, communicated to the Society of Arts a process for preparing crayons, which are stated to be of a quality greatly superior to those commonly or previously in use, being fixed so as to prevent their being rubbed off the paper when used, and are applicable alike to water or oil paintings. These crayons are made of bone-ash powder, mixed with spermaceti, adding thereto the colouring matters. The proper proportion is three ounces of spermaceti to one pound of the powder. The spermaceti to be first dissolved in a pint of boiling water, then the white bone-ash added, and the whole to be ground well together with as much of the colouring matter as may be necessary for the shade of colour wanted. They are then to be rolled up in their proper form, and gradually dried upon a board.

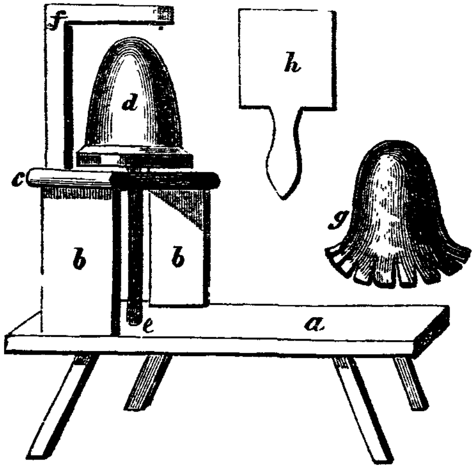
CREAM. The oily part of milk which rises to the surface of that liquid, mixed with a little curd and serum. When churned, butter is obtained. Heat separates the oily part, but injures its flavour.

CROWN SAW. A species of circular saw formed by cutting the teeth round the edge of a cylinder.

CRUCIBLE. A pot in common use for a variety of chemical purposes. It is generally made of clay, and is designed to withstand a strong heat. The best crucibles for this purpose are the Hessian crucibles, composed, according to Pott, of a mixture of very refractory clay with sand. The vessels are not turned upon a potter's wheel, but the earth is kneaded into a very stiff mass, and the form given by ramming it in an iron mould. A composition consisting of two parts of Stourbridge clay, and one part of the hardest coke, well ground and tempered together, has been employed with excellent results by Mr. Anstey, of Somers Town. The following description of his process is an extract from his account published in the *Transactions of the Society of Arts*:—

"Take two parts of fine ground raw Stourbridge clay, and one part of the hardest gas coke, previously pulverized, and sifted through a sieve of one-eighth of an inch mesh. Mix the ingredients together with the proper quantity of water, and tread the mass well (if the coke is ground fine the pots are very apt to crack). The pot is moulded by hand on a wooden block, as shown in the engraving in the next page, in which *a* is the bench; *b b* two uprights supporting a cross-board *c*; *d* the wooden block on which the pots are moulded, supported on a spindle *e* which turns in a hole in the bench; *f* a gauge to regulate the thickness of the melting pot, as shown in the dotted lines; *g* a cap of linen or cotton, placed wet on the core before the clay is put on—its use is to prevent

the clay from sticking partially to the core while it is taking off; the cap adheres to the pot only while wet, and may be renewed without trouble or hazard (to the pot) when dry; *h* a wooden bat to assist in moulding the pot; when moulded, they are carefully dried at a gentle heat. A pot dried as above, when wanted for use, is first warmed by the fire-side, and is then laid in the furnace with the mouth downwards (the red cokes being previously damped with cold ones in order to lessen the heat); more coke is then thrown in till the pot is



covered, and it is then brought up gradually to a red heat. The pot is then turned and fixed in a proper position in the furnace, without being allowed to cool, and is then charged with cold iron, so that the metal, when melted, shall have its surface a little below the mouth of the pot. The iron is melted in about an hour and a half, and no flux or addition of any kind is made use of. A pot will last for fourteen or even eighteen successive meltings, provided it is not allowed to cool in the intervals; but if it cools, it probably cracks. These pots will bear a greater heat than others without softening, and will, consequently, deliver the metal in a more fluid state than the best Birmingham pots will." Crucibles are also sometimes made of porcelain, plumbago, iron, silver, and platina.

CRYSTALLIZATION. That process of nature by which the particles of bodies are arranged systematically in passing from a liquid to a solid state. The phenomena of crystallization have much engaged the attention of modern chemists, with a view to determine exactly the different figures assumed by salts in crystallizing; but it does not yet appear that any certain rule can be laid down in these cases, as these figures may be varied by the slightest circumstances, so that the same salt frequently assumes various figures, and very different substances sometimes present themselves under absolutely the same form. The most diligent observer of the phenomena of crystallization, and who has been most successful in deducing a plausible theory from these observations, is M. Haüy; to whose work, on the *Theory and Structure of Crystals*, we would refer the reader who is desirous of obtaining the best information on the subject.

CUCURBIT. A chemical vessel commonly called a body, made of earth or glass, in the shape of a gourd, and therefore called a cucurbit. It is used in place of a still for distillation.

CUPEL. A shallow earthen vessel used in that part of the process of assaying termed cupellation. It is made of the phosphate of lime, or the residue of burnt bones, rammed into a mould, which gives it its figure.

CUPELLATION. A process in assaying for freeing gold, silver, and platina, from alloys of other metals. It is performed as follows:—the precious metal is put together with a due proportion of lead into a cupel, and the fusion is effected by exposing them to a considerable heat in a muffle or small earthen oven fixed in the midst of a furnace. The lead continually vitrifies or becomes converted into a glassy calx, which dissolves all the imperfect metals. This fluid glass, with all its contents, soaks into the cupel, and leaves the precious metal in a state of purity. During the cupellation, the scoriæ running down on all sides of the metallic mass produce an appearance called circulation, by which the operator judges whether the process is going on well. When the metal is nearly pure, certain prismatic colours flash suddenly across the surface of the globule, which soon afterwards appears very brilliant and clean; this is called brightening, and shows that the operation is ended. After gold has passed the cupel, it may still contain either of the other perfect metals, platina and silver. The former is seldom suspected; the latter is separated by the operation called quartation and parting.

CUPOLA, in Architecture, an hemispherical vault: this term is also applied to the furnaces used for melting iron. See FOUNDRY.

CURRYING is the art of preparing leather after it has been tanned, with oil, tallow, and other matters calculated to give it pliability or suppleness, and durability. See LEATHER.

CUTLERY is a general term applied to table knives, forks, scissors, pocket knifes, razors, lancets, swords, and to a great variety of the more delicate kinds of cutting instruments; it is distinguished from *edge tools* by the latter applying to the coarser kinds of cutting instruments employed by artificers and mechanics, such as axes, adzes, chisels, gouges, gravers, &c.; nevertheless, in some of these it is necessary to the skilful operator to have the utmost precision of form and finish given to their cutting edges.

CYCLOGRAPH. An instrument used for describing arcs of circles in cases where compasses cannot be employed. The most simple cyclograph is that commonly used by artificers in describing arches for the tops of doors and windows, which consists of two rods connected together at such an angle that the apex may touch the highest point of the curve, whilst the sides of the rods are in contact with points fixed in the extremities of the curve, and by turning the instrument round, keeping the two legs in contact with the points at the extremities of the curve, a tracing point in the apex will describe the required arc. An improved instrument on this principle, invented by Mr. Rotch, is described in the *Transactions of the Society of Arts*.

CYCLOID. That curve which is described by a point in the circumference of a circle, during the revolution of the circle over a plane.

CYDER. A fermented beverage prepared from the juice of apples. Large quantities of this liquor are made annually in England; that made in Herefordshire and Devonshire is generally accounted superior to any other. The best practical directions on the art of preparing this liquor that have been given to the public, are those of Messrs. Marshall, Crocker, and Knight, from which chiefly the following account is compiled. The process may be divided into three distinct parts. 1st. Preparing the fruit. 2d. Grinding and expressing the juice. And 3d. Fermenting and bottling.

1st. *In preparing the fruit* care must be taken both as to its peculiar quality and its stage of ripeness. Mr. Marshall is of opinion that the fruit should not be gathered until fully ripe, which is when they begin to fall from the trees; but as apples ripen very unequally on the same tree, he recommends that the trees should first be gone over with a hook when the fruit begins to fall naturally, and that they should be finally cleared with poles when all is ripened, or the winter likely to set in. When the fruit has been gathered, it is usual to lay them in heaps to sweat, but this appears to be only useful for such fruit as is not perfectly ripe.

2d. *Grinding and Pressing.* The grinding is usually performed in a mill nearly resembling a tanner's mill for grinding bark, and consists of a millstone from 2½ to 4½ feet in diameter, from 9 to 10 inches in thickness, and 1 to 2 tons'

weight, and running on its edge in a circular stone trough. The bottom of the trough in which the stone runs is somewhat wider than the stone itself; the inner side of the groove rises perpendicularly, but the outer side is bevelled in such a manner as to make the trough 6 or 8 inches wider at top than at bottom. The runner or millstone turns upon a long shaft or axle passing through its centre; the inner end of the shaft rests upon a pivot in the centre of the mill bed, and the outer end extends beyond the circular trough, and is there connected with a spring bar, to which a horse is attached. After the fruit is ground it generally remains some time before it is pressed, to allow the rind and seeds to communicate their virtues to the liquor: from twelve to sixteen hours is sufficient for this purpose. In order to press the fruit, or pommage, as it is now called, it is folded up in pieces of hair cloth, or placed between layers of clean sweet straw or reed. The bed of the press, which is about 5 feet square, should be made entirely of wood or stone, the practice of covering it with lead being extremely pernicious. It has a channel cut a few inches within its outer edges to catch the liquor as it is expressed, having under it a stone trough or wooden vessel to receive it. The press is worked by levers of different lengths, first a short one, then a longer one, both worked by hand, and lastly a bar 8 or 9 feet long, worked by a capstan or windlass.

3d. *Fermentation.* The common practice is to have the liquor tunned immediately, and to fill them quite full, but it is more proper to leave a small space to be filled up afterwards. No ferment is added, as in malt liquors, but Mr. Marshall thinks it would be desirable to do so, as it would more speedily determine the fermentation, which at present is very precarious as to the time of its commencement and its duration. The process of fermentation is variously conducted by different cyder growers, some endeavouring to promote it in a spacious open vat, whilst others endeavour to repress it by enclosing the liquor in hogsheads, and excluding the air. After remaining a certain time in the fermenting vessel, it is racked off from the leys and put into a fresh cask. A fresh fermentation usually commences after racking, and if it becomes violent a fresh racking is necessary to check it; but if only a small degree of fermentation takes place, termed fretting, the liquor is suffered to remain in the same cask. Mr. Crocker says, when the fermentation ceases, and the liquor appears tolerably clear to the eye, the pure part should be racked off into open vessels, and placed in a cool situation for a day or two, after which it may be again barrelled, and placed in some moderately cool situation for the winter.

D.

DAIRY is the art of manufacturing various kinds of food from milk; the term dairy is likewise applied to the building where those operations are performed. The great variety of business in a well-conducted dairy requiring the most minute and assiduous attention, may be conceived by just stating the principal heads; namely, the proper choice, food, and management of cows; the mode of milking, according to the variation of circumstances; the management of the milk and cream preparatory to the making of butter; the processes of making butter according to the mechanism used for that purpose; the manner of making the various kinds of cheese; the vatting, pressing, and salting the same, &c. These important subjects, which scarcely fall within the plan of this work, are most ably treated, in all their interesting details, in the *Oxford Encyclopædia*, from which valuable publication we extract the following observations on the proper position, structure, and arrangement, of a dairy and its utensils. As respects the dairy-house, the author observes, "It is a matter of considerable importance that buildings of this description should be placed in a proper situation, with respect to the other parts of the farm; this will save both expense and labour, as well as promote convenience. Another principal object in choosing a situation for the dairy is a proper degree of temperature for carrying on the business which is to be conducted in it. To accomplish this, the following are the chief objects to be aimed at. The dairy buildings should

be situate sufficiently near the sheds or cow standings, that the milk may be readily conveyed to them, the form being such as to combine well with the nature of the other erections. The door or entrance into the room destined for the milk should be made through that of the scalding room, which should have the copper for heating water and other purposes, placed in a shed without it, that the heat may be kept at as great a distance as possible from the milk, a cock being fixed in the bottom of it for conveying the heated water through a trough or pipe across the scalding room, in which another cock should be fixed for the convenience of washing smaller utensils, passing the wall into the milk-leads, pans, trays, or coolers, that whenever they are required to be scalded the boiling water may at once pass through the whole range of them, or be detained at pleasure in any one of them, so as to effect the business in the most complete and perfect manner, being afterwards taken off by a suitable drain made for the purpose. The passage of the water through the wall of the dairy should be in a trough of sufficient dimensions to admit the discharging of a pail full of milk into it with perfect safety, having a hair sieve so placed in it as that the whole of the milk of the cows may be made to pass through it into the necessary trays or coolers in which it is to stand, as by this simple contrivance the necessity of dirty men or boys entering the dairy-house is wholly prevented. There should be likewise a trough, pipe, or some other similar contrivance, for the purpose of conveying the waste milk, whey, &c., from the dairy-house to the cisterns for containing the wash for the pigs, &c. Several plans for regulating the temperature of the dairy have been proposed by different persons. It may be accomplished in various ways, as by having double walls and roofs, or by hollow walls, or by the walls having a vacuity left of eight or ten inches in width between the lath and plaster. A spring or fountain rising in the centre of the principal apartment, when it can be procured, will be a most valuable convenience. It is obvious that the nature and number of these buildings on any farm must depend on the kind of dairy business proposed to be carried on, whether milk, or butter, or cheese; and the size is always regulated by the number of cows. The dimensions usually adopted in Gloucestershire are 20 feet by 16 for forty cows; and 40 feet by 30 for one hundred cows. It is well known that without a suitable place for preserving the milk and performing the various operations, the dairy business cannot proceed with any prospect of advantage. To preserve an equable temperature, a northern aspect has been suggested as the most proper. These apartments should be dry, and to render them clean and sweet at all periods without much trouble, their situation should be in the immediate neighbourhood of a spring or clear rivulet. The roof and walls should also be defended from the action of the sun's rays by shady trees, buildings, &c. For the milk dairy two good rooms are all that are necessary; namely, one for scalding, cleaning, and airing the utensils, and the other for the reception of the milk. For a butter dairy three apartments will be required; one for holding, washing, scalding, and airing the utensils; one for keeping the milk; and one for churning the butter. Four apartments are necessary to a well-constructed cheese dairy; namely, one for the reception of the milk: another for the scalding and pressing of the cheese; a third, where it is salted; and a fourth, called the cheese-loft, in which the cheeses are deposited." As respects the dairy utensils, our writer states, that "the only proper materials for making the vessels and implements belonging to a dairy are wood, porcelain, glass, and slate; they are, however, made mostly of wood, as glass and porcelain are too expensive; slate has lately been employed in constructing milk coolers." Tinned iron is, however, often used for skimming dishes and other purposes; lead and glazed earthenware form many of the utensils in some dairies, and cast iron has been recommended for the same purpose: but it will be proper to observe that lead is poisonous, and so are some of the metallic substances that enter into the composition which forms the glazing of earthenware. Now, since milk contains acids capable of dissolving these metallic compounds, it must follow that the use of them in a diary must be very prejudicial. The human constitution must infallibly be injured by imbibing these deleterious solutions; but the progress of the mischief is slow;

and when at length the mischief is discovered, we seldom or never ascribe it to the proper cause. Nor is the use of iron to be recommended, for though its solution in the acid of milk may be harmless, yet the milk, butter, and cheese, into which this solution enters, may be altered in their taste, and acquire new properties from it. The best vessels and utensils for the dairy are, therefore, those which are made of wood, and which are kept in a sweet and clean state by daily scalding, scouring, &c. The utensils which are most generally wanted in a dairy farm, are milk-pails, skeels, bowls, strainers and coolers, churns, lading and skimming dishes, cheese tub, ladders, vats, cloths, and presses. The fitting a dairy, where one churn is used, with these utensils, will cost from twenty to twenty-four pounds,—this is the estimated value in Gloucestershire; in a farm consisting of twenty-five or thirty cows the cost would probably be double that sum, and so on, in proportion to the magnitude of the farm.

DAMAJAVAG. This singular name has been given to a preparation of the chestnut tree, and is employed in tanning as a substitute for oak bark and gall nuts: it is the subject of a patent granted to Charles Louis Giroud, of Queen-street, Soho, London, in 1825. The mode of preparing damajavag is as follows: The external shell of the chestnut, or the wood itself, is to be broken into small pieces, and soaked in double its weight of water for twelve hours, then boiled for three or four hours, when the liquid is to be drawn off, and filtered through a cloth or sieve to separate the fibrous matter. The liquid extract is now to be evaporated by returning it into the boiler, and the ebullition is to be renewed and continued until the extract becomes of the consistency of paste; after this it is to be cut into cakes, and dried in an oven for sale, or at once applied to the various purposes in the arts, in lieu of gall nuts. One hundred pounds of chestnut shells will thus produce about eight pounds of damajavag. The sap of the chestnut tree contains similar properties to the wood and the nut shell, but combined with a greater portion of mucilage. The trunks of the trees may be tapped, the sap collected, and an extract made from it by simple evaporation. Iron vessels should not be used in the preparation of damajavag, as that metal would darken the colour of the extract, owing to the affinity between iron and the gallic acid of the chestnut, their combination producing ink.

DAMASK. The name given to silk or linen fabrics with a raised pattern on the right side.

DAMASKENING. The art of beautifying iron, steel, &c. by making incisions in them, and filling them up with gold or silver wire; it is chiefly used for adorning sword blades, locks of pistols, &c. See Iron.

DAVIT. A projecting piece of timber, used as a crane to hoist the flukes of the anchor to the top of the bow of a ship.

DEAD LIGHTS. Strong wooden shutters for closing the stern windows of a ship in bad weather.

DEAD RECKONING. An account of the progress of a vessel, showing the courses steered by compass, with the distance in miles and fathoms run upon each course. These courses, corrected by allowances for leeway and variation, and the distances by allowances for heave of the sea and currents, form what is termed the corrected dead reckoning, which is used for ascertaining the vessel's place upon a chart, in default of observations of the celestial bodies to determine the same.

DEAL. A stout kind of plank made from the fir-tree by sawing the trunk longitudinally.

DECIMAL ARITHMETIC, in general sense, denotes the common arithmetic in which we count by periods of tens; it is otherwise and more properly called denary arithmetic, to distinguish it from the binary, duodenary, and other scales of arithmetic.

DECOCTION. A fluid which has been made to take up certain soluble principles by boiling.

DECOMPOSITION, in Chemistry, the separation of the component parts of bodies from each other. It is in general the effect of some new combination amongst the constituent principles of bodies, the only exceptions being those decompositions which are effected by heat or electricity.

DECREPITATION. The crackling noise which several salts make when suddenly heated, accompanied by a violent exfoliation of their particles. It has been attributed to the sudden conversion of the water they contain into steam; "but," observes Dr. Ure, "it is the salts which are anhydrous, or contain no water, that decrepitate most violently; those that contain water generally enter into tranquil liquefaction on being heated." Salts decrepitate for the same reason that glass, quartz, and cast iron crack with an explosive force, on being suddenly heated, namely, from the unequal expansion of the laminæ which compose them, in consequence of their being imperfect conductors of heat.

DEFLAGRATION. The act of burning two or more substances together, as charcoal and nitre.

DEFLEXION, in Mechanics, the bending of any material exposed to a transverse strain. In all bodies so situated deflexion takes place; but whilst the elastic force of the material exceeds the straining force, the deflexion will be directly proportional to the pressure, and will not increase after the load has been on for a second or two, and upon its removal the material will recover its original form; but if the load exceed the elastic force of the material, the extension or deflexion increases with time, a permanent alteration of form ensues, and the deflexion increasing rapidly with slight addition to the load, fracture ensues. The resistance of a material to flexure, as Mr. Tredgold observes, is the only proper measure of its resistance, when it is to be applied in the construction of buildings, and that of its resistance to permanent alteration when it is used for machines. According to Mr. T.'s experiments, a bar of cast iron, 4 feet long and 1.2 inches square, and supported at both ends, sustained a load of 112 lbs. in the middle of its length without permanent alteration. The deflexion with this load was one-tenth of an inch.

DEGREE, in Geometry, the 360th part of the circumference of a circle, into which number of parts all circles are considered to be divided; it is indicated by a small $^{\circ}$ near the top of the figure; thus, 45° is forty-five degrees. Each degree is subdivided into sixty smaller parts, called minutes, and denoted by the mark $'$; and these again are each subdivided into sixty parts, called seconds, and marked thus $''$; thus, $45^{\circ}\ 12'\ 20''$ is forty-five degrees twelve minutes and twenty seconds.

DELFT WARE. A kind of pottery, covered with an enamel or white glazing, which gives it the appearance of porcelain. They are composed of a fatty clay, with which is ground a portion of sand, that it may not crack or shrink too much in baking. Vessels formed of this earth require to be dried very gently, to avoid cracking; they are then slightly baked in a furnace, to give them a degree of hardness; after which, the enamel, ground very fine and diluted with water, is applied, and as the ware is very porous from being but slightly baked, it readily absorbs the water, leaving a coating of enamel adhering to the surface. The ware, when thoroughly dried, is then enclosed in cases of baked earth, and subjected to a heat sufficient to fuse the enamel uniformly, and at the same time to complete the baking. Delft ware was formerly made chiefly at Delft, in Holland, from which town it takes its name.

DELIQUESCENT, in Chemistry, a property of various substances (chiefly salts), to absorb moisture from the atmosphere, and dissolve.

DENDROMETER. An instrument for measuring trees, invented by Messrs. Duncombe and Whittel. It consists of a semicircle, divided into two quadrants, and graduated from the middle; upon the diameter there hangs a plummet for fixing the instrument in a vertical position. The principal use of it is for measuring the length and diameter of any tree perpendicular or oblique to an horizontal plane, or in any situation of the plane on which it rests; or of any figure, whether regular or irregular, and also the length and diameter of the boughs, by mere inspection. The inventors of it have calculated tables, annexed to their account of the instrument itself, by the help of which the quantity of timber in a tree is obtained without calculation, or the use of the sliding rule. The dendrometer, fitted to a theodolite, may be applied to measuring the heights and distances of objects accessible or inacces-

sible, whether situated in planes parallel or oblique to the plane on which the instrument is placed. It may be also used for taking all angles, whether vertical, horizontal, or oblique, in any position of the planes in which they are formed.

DENSITY is the proportionate quantity of matter in bodies of a given magnitude; thus, if a body contains more matter than another, both being of the same bulk, the former is said to be more dense than the latter, and that in proportion to the relative quantities of matter they contain; or if the former body contains the same quantity of matter as the latter, but under a less bulk, its density is greater in proportion as its bulk is less than that of the other. Hence the density is directly proportional to the quantity of matter, and inversely proportional to the bulk under which it is contained. The relative quantities of matter in bodies are known by their gravity or weight; for, according to Sir Isaac Newton, the original particles of matter being equal, and consequently endowed with equal gravity, bodies, or assemblages of those particles, will have a gravity proportionate to the number of particles contained in them. Hence, when a body, mass, or quantity of matter is spoken of, its weight or gravity is always understood, that being the proper measure of the quantity of matter. The density of bodies is found by weighing equal bulks of each; for this purpose solids must be previously reduced to the same shape and size, but each fluid should fill the same vessel, in which they must be weighed separately. The density of fluids may also be determined by the following methods. First, by making an equilibrium between them, in tubes that communicate; for the diameters of the tubes being equal, and the weights or quantities of matter also equal, the densities will be inversely as the altitudes of the liquors in them; that is, inversely as their bulk. Secondly, by immersing a solid in the fluids, their densities may be readily compared; for if the solid be lighter than the liquids, the part immersed by its own weight will be inversely as the density of the fluid; but if the body be heavier, so as to sink in the liquid, it must be weighed in them separately, and the weight lost by the body in each will be directly as the density of the fluid. Sir Isaac Newton, and most of the other philosophers, are of opinion that there is no such thing as a space absolutely full of matter, and that consequently there is no substance in nature, either solid or fluid, that is perfectly dense: the densest bodies, according to Newton, consist of much more porous space than solid matter.

DEPARTURE, in Navigation, the distance of a ship or place to the east or west of any meridian, expressed in *nautical miles*, whilst the difference of longitude is the same distance reckoned in degrees and minutes upon small circles of the earth, termed parallels of latitude; and as these small circles continually decrease as they approach the poles, and as every circle, large or small, contains 360°, each containing $60'$, the length of the degrees and minutes of longitude must vary with the latitude.

DEPHLEGMATION. The operation by which bodies are deprived of water, which is principally effected by evaporation.

DEPHLOGISTICATION. The operation by which bodies are deprived of phlogiston, or the inflammable principle, and nearly synonymous with what is now expressed by oxygenation or oxidization.

DESCENDING CLOCK. A clock so constructed that by gradually rolling down an inclined plane it shows the progress of time; the motion is communicated to the wheels by a weight, which revolve about the axis as the clock descends. A drawing and description of this machine is given in *Emerson's Mechanics*.

DESIGNING is the art of delineating or drawing the appearance of objects by lines on a plane; but the term is more generally understood to apply to the first sketch of a work which it is intended afterwards to execute with greater accuracy of detail or of finish, or upon a different scale of magnitude. A design bears the same relation to drawing and painting as a model does to the making of a machine or building.

DETENT, in Clock-making, a stop, which, being lifted up and let fall down, locks and unlocks the striking parts of a clock.

DETONATING JAR. An apparatus for firing a mixture of gases by

means of the electric spark. It consists of a thick glass tube, open at bottom, but hermetically sealed at top, and having towards the upper part two small wires cemented into it, which approach each other within the jar near enough to communicate the electric spark from an adjoining machine, by which the gases are fired.

DETONATING POWDERS, or Fulminating Powders. Certain chemical compounds, which, on being exposed to heat or friction, explode with a loud report, owing to one or more of the constituent parts assuming the elastic state with such rapidity as to strike the displaced air with great violence. The most common detonating powders (except gunpowder), are fulminating gold, and fulminating powder. This latter is made by triturating, in a warm mortar, three parts by weight of nitre, two of carbonate of potash, and one of flowers of sulphur. When fused in a ladle and then set on the fire, the whole of the melted fluid explodes with an intolerable noise, and the ladle is commonly disfigured as if it had received a strong blow downwards. If a solution of gold be precipitated by ammonia, the product will be fulminating gold. This precipitate, separated by filtration, and washed, must be dried without heat, as it is liable to explode with no great increase of temperature; nor must it be put into a bottle with a glass stopper, as the friction of this would expose the operator to the same danger. Less than a grain held over the flame of a candle explodes with a very sharp and loud noise. Fulminating silver may be prepared as follows: powder one hundred grains of nitrate of silver, put the powder into a glass vessel, and pour upon it first an ounce of alcohol, and then as much concentrated nitrous acid. The mixture grows hot, boils, and an ether is visibly formed, that changes into gas. By degrees the liquor becomes milky and opaque, and is filled with small white clouds. When all the grey powder has taken this form, and the liquid has acquired consistency, distilled water must be immediately added, to suspend ebullition and prevent the matter from being redissolved and becoming a mere solution of silver. The white precipitate is then to be collected on a filter, and dried. The force of this powder greatly exceeds that of fulminating mercury: it detonates in a tremendous manner on being scarcely touched with a glass tube, the extremity of which has been dipped in concentrated sulphuric acid. Fulminating mercury was discovered by Mr. Howard. A hundred grains are to be dissolved with heat in an ounce and a half by measure of nitric acid. The solution, when cold, is to be poured on two ounce measures of alcohol, and heat applied till an effervescence is excited. As soon as the precipitate is thrown down, it must be collected on a filter, that the acid may not react on it, washed, and dried by a very gentle heat. It detonates with very little heat or friction. Three parts of chlorate of potash, and one of sulphur, triturated in a metal mortar, cause numerous successive detonations, like the cracks of a whip, the reports of a pistol, or the fire of musketry, according to the rapidity and force of the pressure employed. A few grains struck with a hammer on an anvil explode with a noise like that of a musket, and torrents of purple light appear around it. Six parts of the chlorate, one of sulphur, and one of charcoal, detonate by the same means, but more strongly, and with a redder flame. Sugar, gum, or charcoal, mixed with the chlorate, and fixed or volatile oils, alcohol, or ether, and made into a paste, detonate very strongly by the stroke, but not by trituration. Some of them take fire, but slowly and by degrees, in sulphuric acid. Fulminations of the most violent kind require the agency of azote or nitrogen, as we see not only in its compounds with the oxides of gold, silver, and platina, but also still more remarkably in its chloride and iodide, which form the two most violent detonating compounds known. The first of these, viz. the chloride of azote, was discovered in 1812, by M. Dulong, but its nature was first investigated by Sir H. Davy, who was twice seriously wounded by explosions of the substance whilst operating upon it. It may be prepared as follows: put into an evaporating porcelain basin a solution of one part of nitrate or muriate of ammonia, in ten parts of water heated to about 100°, and invert into it a wide-mouthed bottle filled with chlorine. As the liquid ascends by the condensation of the gas, oily looking drops are seen floating on its surface, which collect together, and fall to the

bottom in large globules: this is chloride of azote. By putting a thin stratum of common salt at the bottom of the basin, we prevent the decomposition of the chloride of azote by the ammoniacal salt. It should be prepared only in very small quantities. A small quantity of it thrown into a glass of olive oil, produced a most violent explosion, and the glass, although a strong one, was broken into fragments It also detonates strongly when brought into contact with phosphorus and many of its compounds, with various fixed oils, with oil of turpentine, naphtha, fused potash, aqueous ammonia, nitrous gas, and various other substances, but not with sulphur or resin. Iodide of azote may be most readily prepared by putting pulverulent iodine into common water of ammonia. It is pulverulent, and of a brownish black colour. It detonates from the smallest shock, and from heat, with a feeble violet vapour. When properly prepared, it frequently detonates spontaneously; hence, after the black powder is formed, and the liquid ammonia decanted off, the capsule should be left in perfect repose. Dr. Ure mentions, that in transferring a little of it from a capsule of platina to a piece of paper, the whole exploded in his hands. It should therefore be prepared with the greatest care, and in only very small quantities, and should not be preserved.

DIACOUSTICS. The consideration of the properties of sound refracted in passing through different media

DIAGONAL, in Geometry, a right line drawn across a figure from the vertex of one angle to the vertex of another.

DIAGONAL SCALE. See Scale.

DIAGRAM. A geometrical scheme for the explanation of the properties of a figure, or for the illustration of machinery; in which case it differs from a drawing, by the parts being represented by single lines without any breadth.

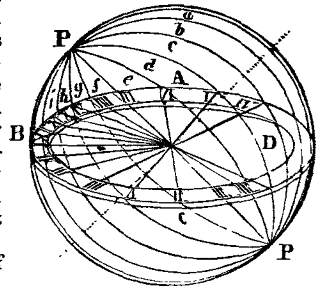
DIAL, or SUN DIAL. An instrument for measuring time by means of a shadow cast by the sun upon a surface properly placed for the purpose. Sun dials are an invention of very great antiquity, and are frequently mentioned in the Bible; and Vitruvius speaks of one made by the ancient Chaldee historian, Berosus, on a reclining plane, almost parallel to the plane of the equinoctial. Before the invention of clocks and watches, dials afforded almost the only means of marking the lapse of small portions of time; and dials were, therefore, generally to be seen in most places of public resort, as churches, crossways, markets, &c.; but since that invention, and the immense improvements made in it, dials have gone gradually into disuse, and are now rarely to be met with in England, where, indeed, the variable nature of the climate materially limits their utility. On the Continent they are still to be met with; and one kind, called the pillar dial, consisting of an elegant stone column, is frequently introduced as an ornament in the squares and market places. Our ingenious neighbours, the French, have likewise contrived a method of calling attention, at least once in the day, to the silent progress of the shadow over the dial, by means of a small mortar placed on the meridian line of a dial with a burning lens placed over the touch-hole, at such a distance and angle, that as soon as the sun arrives on the meridian, its rays, concentrated by the lens, set fire to the powder, which discharges the gun, and thus announces the hour of noon.

> "We take no note of time but from its loss:
> To give it then a tongue is wise in man."

Dials of this description are placed in the gardens of the Palais Royal, and of the Luxembourg.

DIALLING. The art of drawing dials on any surface, plane or curved. On account of the limited utility of this art, from the causes before noticed, we shall confine ourselves to explaining the general principles of dialling, which may be aptly illustrated by the phenomena of a hollow or transparent sphere of glass. Then suppose $a\,P\,B\,p$ to represent the earth as transparent, and its equator as divided into 24 equal parts, by so many meridian semicircles, $a\,b\,c$, &c., one of which is the geographical meridian of any given place, as London, which is supposed at the point a; and if the hour of 12 be marked upon that meridian, and upon the opposite one, and all the rest of the hours in succession on the other meridians, those meridians would be the hour circles of London; because, as the

sun appears to move round the earth, which is in the centre of the visible heavens, in twenty-four hours, he will pass from one meridian to another in an hour. Then, if the sphere had an opaque axis as P *e* P, terminating in the poles P and P, the shadow of the axis, which is in the same plane with the sun and with each meridian, would fall upon every particular meridian and hour when the sun came to the plane of the opposite meridian, and would, consequently, show the time at London and at all other places on the same meridian. If this sphere were cut through the middle by a solid plane A B C D in the rational horizon of London, one-half of the axis *e* P would be above the plane, and the other below it; and if straight lines were drawn from the centre of the plane to those points where its circumference is cut by the hour circles of the sphere, those lines would be the hour lines of an horizontal dial for London; for the shadow of the axis would fall upon each particular hour line of the dial when it fell upon the like hour circle of the sphere. Those who are further interested in the subject we would refer to Emerson's *Dialling*, and Ferguson's *Lectures on Mechanics*. Dr. Brewster, in the Appendix to his valuable edition of this latter work, has described an analemmatic dial, which sets itself. Many ingenious constructions of dials are also given in Dr. Hutton's *Translation of Montucla's Recreations*.



DIAMETER, in Geometry, the line which, passing through the centre of a circle, or other curvilinear figure, divides it or its ordinates into two equal parts.

DIAMOND. The most brilliant and the most valued of all the minerals. It is found of all colours—white, grey, red, brown, yellow, green, blue, and black; the colourless varieties are the most esteemed. If very transparent and pure, they are said to be of the first water; and in proportion as they depart from this transparency and purity, they are denominated of the second or third water. The extraordinary lustre of the diamond is said to be derived from its reflecting all the light which falls on its posterior surface at an angle of incidence greater than 24° 13′; artificial gems reflect only half this light. The weight, and, consequently, the value of diamonds, is estimated in carats, one of which is equal to four grains; and the piece of one diamond, compared to that of another of equal colour, transparency, purity, form, &c., is as the squares of the respective weights. The average price of rough diamonds that are worth working is about two pounds for the first carat; and the value of a cut diamond being equal to that of a rough diamond of double weight, exclusive of the price of workmanship, the cost of a wrought diamond of

1 carat is	£	£8
2 ditto is	$2^2 \times 8 =$	32
3 ditto is	$3^2 \times 8 =$	72
4 ditto is	$4^2 \times 8 =$	128
5 ditto is	$5^2 \times 8 =$	200

This rule is, however, not extended to diamonds of more than 20 carats (value 3,200*l.*); the larger ones, in consequence of the scarcity of purchasers, being disposed of at prices greatly inferior to their estimated worth. It does not appear that a larger sum than 130,000*l.* was ever given for a diamond, which was brought by a gentleman named Pit, from India, and was hence called the Pit diamond. Diamonds can only be cut and polished by their own substance. The operation is commenced by rubbing several against each other while rough, after having first glued them to the ends of two wooden blocks, thick enough to be held in the hand. The powder thus rubbed off the stones

is received into a little box for the subsequent purposes of grinding and polishing them. These operations are effected by a mill, which turns a wheel of soft iron, on which is sprinkled the diamond dust, mixed with oil of olives; the particles of diamond becoming imbedded in the soft iron by the rubbing action, and presenting a multiplicity of opposing cutting angles to the stone under operation, which is thereby shaped according to the design of the operator. The same dust well ground and diluted with water and vinegar is used in the sawing of diamonds, which is performed by an extremely fine iron or brass wire; the operation being similar in principle to the sawing of blocks of stone for the use of the mason, by means of sharp sand and a blunt blade of iron. Brilliants are those diamonds which are cut in faces at the top and bottom, and whose table or principal face at top is flat. Rose diamonds are quite flat underneath, with the upper part cut into many little facets, usually triangles, the uppermost of which terminates in a point. The only chemical difference between diamond and the purest charcoal is, that the latter contains an extremely minute portion of hydrogen. It is said that diamonds have been recently artificially produced from charcoal.

DIAPASON. An interval in music that expresses the *octave* of the Greeks. This term is likewise applied to the rule or scale whereby musical instrument makers adjust the pipes of organs, and cut the holes of hâutboys, flutes, &c. in due proportion, for performing the tones, semi-tones, and concords, with precision.

DIAPER. A kind of cloth, on which is formed a variety of designs, chiefly employed for table linen. See WEAVING.

DICE. Small cubical pieces of bone or ivory, marked with dots on each face, from one to six. To give uniformity to their figure, or to make true dice, is of course a very simple art; but the ingenuity of the dice-maker is called into action to construct false or untrue dice for the sharping gamester; for him they are so skilfully constructed or loaded, as to ensure a preponderance of favourable chances, without incurring the probability of the cause being discovered. Some of their nefarious processes are known to us, but it is not our province to extend the knowledge of so vile an art.

DIFFERENCE is the remainder after taking the less of two quantities from the greater.

DIFFERENTIAL, in the higher Geometry, is an infinitely small quantity, or part of quantity, so small as to be less than any assignable one, and is thus denominated because it is frequently considered as the difference of two quantities, and as such, is the foundation of the differential calculus. The term differential is also applied, in Mechanics, to various machines for imparting to a body the difference of motion of two other bodies moving in contrary directions; an example of this is shown in the Chinese crane, under the article CRANE. For further instances, see PULLEY DIFFERENTIAL, SCREW DIFFERENTIAL, and WHEEL DIFFERENTIAL.

DIGESTER. A strong vessel formed of iron or copper, the lid of which screws down, and is made tight by luting or grinding; and the steam not being allowed to escape, the water acquires a very high temperature, by which its solvent powers are greatly increased. To prevent accidents, a small safety valve is inserted in the lid. The digester is the invention of the celebrated Papin.

DIGIT, in Arithmetic, any one of the ten numerals 1, 2, 3, 4, 5, 6, 7, 8, 9, 0; also a measure equal to three-quarters of an inch.

DILATATION. The expansion of a body into a greater bulk by its own elastic power. It differs from rarefaction: for though the effects of both are nearly, if not quite the same, yet the latter arises from the application of heat. It has been observed by modern philosophers, that bodies which have been compressed and are again set at liberty endeavour to dilate themselves with a force equal to that by which they are compressed; accordingly they are found to sustain a force and raise a weight equivalent to the force of compression. Bodies in the act of dilating by their own elasticity exert a greater force at the beginning than towards the end, as being at first more compressed; and the

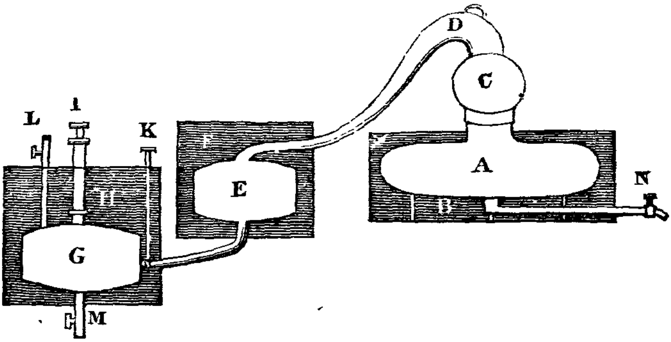
greater the compression is the greater is the elastic power and endeavour to dilate: hence the compressing power, the compression, and the elastic force, are necessarily equal, and may be taken the one for the other. The motion by which compressed bodies restore themselves is usually accelerated, though sometimes not. When compressed air begins to restore itself, and dilate into a larger space, it is still compressed, consequently new impetus is continually impressed upon it by the dilatative cause; and the former remaining with this continual addition, the effect, namely, the velocity, must likewise evidently be increased. But it may also happen, that where the compression is only partial, the motion of dilatation will not only not increase, but be even retarded, as is the case when sponge, soft bread, gauze, and other similar bodies, are compressed.

DIOPTRICS. The doctrine of refracted vision, which investigates and explains the effects of light refracted by passing through different media, as air, water, glass, &c.

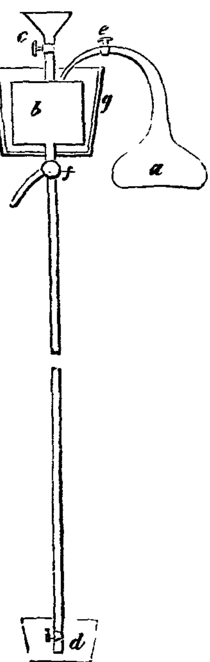
DISTILLATION. The art of obtaining in a separate state, by the application of heat, the more volatile parts of bodies; but the term is generally limited to signify the separation of volatile liquids, for when the volatile product is obtained from a solid, and assumes a solid form, the operation is termed sublimation. In the distillation of liquids the most volatile parts rising in vapour first are conducted to variously disposed refrigerators, usually composed of metal, and surrounded with cold water, which, abstracting a portion of heat from the vapour, it becomes condensed, and assumes a liquid form. One of the principal applications of the art of distillation is the preparation of spirituous liquors, which is usually divided into two branches. The first, termed *distillation*, consists in separating the spirituous parts of fermented liquors, mixed with a large portion of water, from the fixed or nonvolatile parts; and in the latter branch, termed *rectification*, the spirit is concentrated and purified principally by means of redistillation. Having already treated largely upon the various methods of effecting this, under the head Alcohol, we shall in this place limit ourselves principally to the description of the preparatory process of distillation, together with some of the most approved apparatus employed therein.

In London and its neighbourhood the process of forming the wash for distillation is the same as in brewing for beer, except that no hops are used, and that instead of boiling the wort they pump it into coolers, and afterwards draw it into backs, to be then fermented with yeast. During the fermentation, considerable attention should be paid to the temperature of the liquid, which should be steadily maintained at about 70° Fahr., and the fermentation is continued until the liquor grows fine and pungent to the taste, but not so long as to allow acetous fermentation to commence. In this state the wash is put into the still (of which it should occupy about three-fourths), and distilled with a gentle fire as long as any spirit comes over, which is generally until about half the wash is consumed. The form of the common still is too well known to need any particular description. It generally consists of a large boiler made of copper, and fixed in masonry over a fire-place. The boiler has a head, or capital, as it is called, which is of a globular form, to which is soldered a neck, forming an arch curved downwards, and fits into what is called the worm: this is a long tube, made generally of pewter, of a gradually increasing diameter; it is curled round in a spiral form, and enclosed in a tub, which is kept filled with cold water during distillation. That celebrated philosopher and mechanic, the late Mr. Watt, having ascertained that liquids boil in vacuo at a much lower temperature than when under the pressure of the atmosphere, endeavoured to turn this circumstance to advantage in distillation, under the idea that less fuel and also less water for condensation would be required; but found, by experiment, little or no advantage in this respect, the latent heat of the vapour being nearly the same, whether formed in vacuo or under the pressure of the atmosphere. The idea of distillation in vacuo was subsequently taken up by Mr. Tritton, as affording a means of preventing any empyreumatic flavour being imparted to the spirit by the burning of any matter contained in the still, as a heat considerably less than 212° Fahr. is sufficient to cause the wash to

boil rapidly in vacuo. The annexed diagram exhibits a section of Mr. Tritton's apparatus for distilling in vacuo. A is the body of the still; B is a water



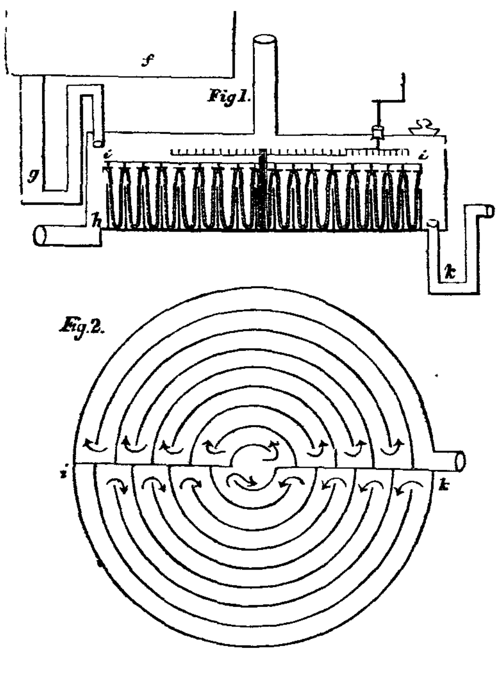
bath, into which the body of the still is immersed; C is the head or capital; D the neck of the same, which, curving downwards, is connected with a pipe that enters the condensing vessel E; F is a refrigeratory or close vessel, containing cold water, for converting into liquid the spirituous vapours, which, having been raised in the still, are contained in the vessel E. From the bottom of the vessel E a pipe issues, for conveying the liquid and the vapour not yet condensed into vessel G, which being surrounded with cold water contained in the vessel H, acts also as a refrigeratory, and reduces the whole of the remaining vapour into a liquid state. I is an air pump for effecting a vacuum in the vessels A E G; K is a stop-cock for cutting off the communication between the vessels E and G, when the contents of G are drawn off by the cock M, by which means a vacuum is preserved during that operation in the vessel E and the still A. L is an air cock, to admit air into the vessel G, to allow the contents to run out at M; N is the discharge cock to the still A. It will be seen that the greatest heat to which the matter in the still can be subjected can never exceed 212° Fahr.; but upon the pressure of the atmosphere being removed by means of the air-pump, the distillation is effected at the low temperature of 132° Fahr., by which means all injury to the flavour of the spirit, by carbonization of the matters contained in the still, is entirely avoided.



Dr. Arnott, in his work on the *Elements of Physics*, proposes a mode of distilling or evaporating in vacuo, without the aid of an air pump, by simply establishing a communication between a close distilling or evaporating vessel, and the top of a water barometer. The principle of this method will be readily comprehended by referring to the annexed diagram and its accompanying explanation. *a* is the evaporating vessel or still, the neck of which communicates with a strong vessel *b*, forming the top of the barometer; from the under side of *b* proceeds a tube, plunging in a small vessel *d*, situated 36 feet below the bottom of *b*. The cocks at *d* and *e* being shut, the vessel *b* and the descending pipe are to be filled with water through a cock *c* at the top; then

this cock being shut, and the cock at *d* opened, the water will sink down out of the vessel *b* until the column in the tube be only 34 feet high, as at *f*, that being the height which the atmosphere will support. On opening a communication between the vessel *a* and the vacuum in *b*, the operation goes on as desired, and the steam arising from *a* may be constantly condensed by allowing a small stream of water to run through *b* from above, in cases where it is sought to concentrate any liquid in *a* in vacuo; but for distillation, where the condensed vapour is the product which is sought, the water must be applied externally to *b*, by placing that vessel in another vessel *g*, kept constantly full of water. If the vacuum becomes destroyed by the accumulation of the air extricated in boiling, it may be easily restored by refilling *b* as at first. Dr. Arnott states that he planned this arrangement as a simple apparatus for the preparation of medicinal extracts, as many watery extracts from vegetables have their virtues impaired or destroyed by a heat of 212°; but when the water is driven off in vacuo, the temperature need never be higher than blood heat. The doctor further observes, that this plan appears "particularly well suited to the colonies, where air-pumps and nicer machinery can with difficulty be either obtained or managed."

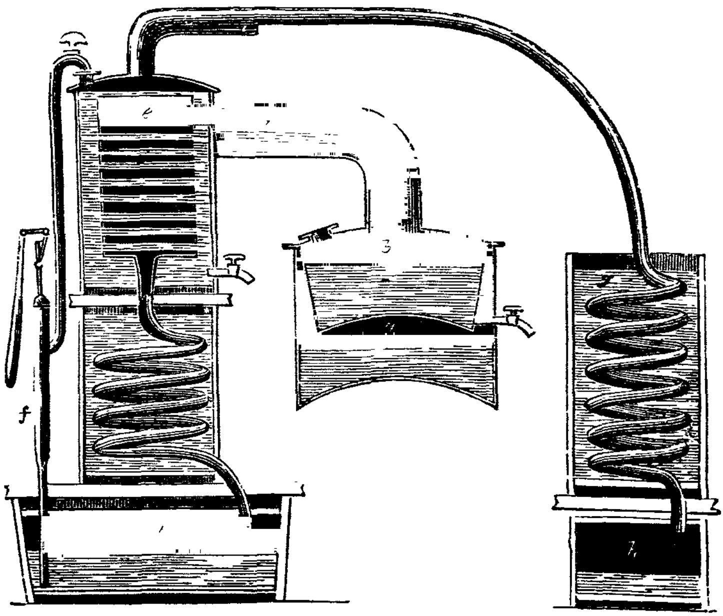
The annexed engraving represents Sir Anthony Perrier's improved apparatus for distillation. The object of this invention is to cause the liquid to flow gradually over the heated surface of the body of the still, and during its progress to give out its spirituous vapour, and to maintain a continuous and



uninterrupted distillation as long as the supply of liquid is furnished and the fire kept up. *Fig.* 1 is a view, in profile, of the section of the still, and *Fig.* 2 is a plan of the same. The bottom of this boiler is divided by concentric partitions, which stand up, as in *Fig.* 1, sufficiently high to prevent the liquor from boiling over. These partitions have openings from one to the other at opposite sides, so as to make the course a sort of labyrinth. *f* is a reservoir of liquor prepared for the operation; *g* is a pipe or tube descending from the reservoir, and

conducting the liquor to that part of the boiler marked *h*, which is the commencement of the race. From hence the liquor flows through the channels, as shown by the bent arrows, progressively traversing the whole surface of the bottom, whereby the full effect of the fire is exerted upon small portions of the liquid, which causes the evaporation to proceed with great rapidity. The residue of the liquid then passes off by the discharge pipe *i*, which is made to slide, for the purpose of regulating the quantity and depth of fluid in the still; and this pipe should be in such proportion to the admission pipe, as to cause the perfect distillation of the liquor in its passage to the regulating tube. In the still, as shown at *Fig*. 1, a set of chains are seen suspended from a bar *i i*, supported by a centre shaft, which may be put in motion by a toothed wheel and pinion, actuated by a crank or winch. These chains hang in loops, and fall into the spaces between the partitions, for the purpose of sweeping the bottom of the still, and preventing the material operated upon from burning, when of a thick or glutinous nature, as turpentine, syrups, &c.

In the still we are now about to describe, invented by Mr. Frazer, of Houndsditch, the object is the economizing of fuel, and the production of a pure spirit, by a peculiar arrangement of the vessels employed, that shall at the same time be in perfect accordance with the existing excise laws. The *wash* still, instead of being exposed to naked fire, is immersed in boiling water, the vapour from the former enters the low wine still, where it is condensed; the wine thus abstracts the heat from the wash, becomes itself vapourized, and is conducted into a refrigeratory; the first and second distillations are in this manner conducted together by a continuous process, which will be best understood by a reference to the annexed diagram. *a* is a supposed steam engine boiler, or

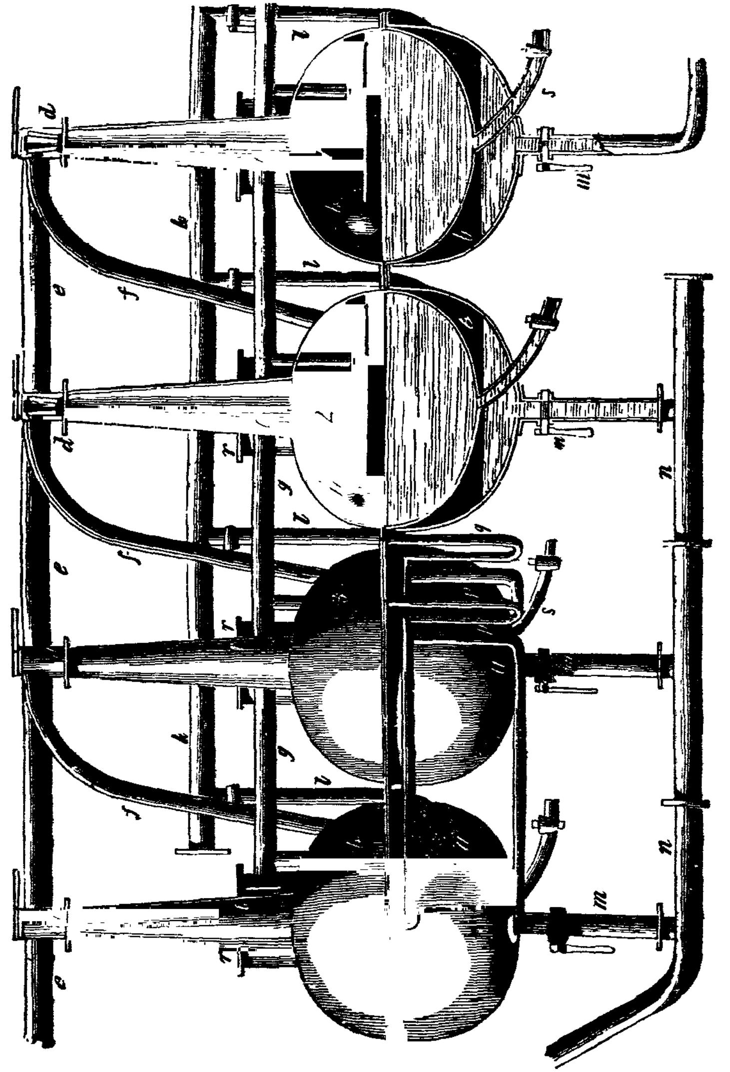


other similar vessel, the heat from which boils the wash (or low wine) in the still *b*. To prevent the liquid from boiling over into the condenser, the neck is formed of the shape shown at *i*; from hence the vapour passes through a steam-tight case *e*, immersed in a reservoir *c*, containing either wash or the product of the first distillation, where it becomes partly condensed; the vapour and condensed liquid then descend through the worm beneath, wherein the

condensation is completed and the liquid cooled, which then runs into the closed recipient *d* underneath. This recipient *d* therefore contains the weak spirit of the first distillation, called low wines, to re-distil which product it is raised by the pump *f*, and discharged into the reservoir *c*, which is, in effect, the low wine still. The liquid in this vessel, as before mentioned, is vapourized by the heat of the vapour from the wash still passing through it; it is afterwards condensed in the refrigeratory *g*, and finally received into the closed vessel *h*, where the operation is completed.

The engraving on p. 440 represents the patent distilling apparatus of Mr. Stein; in appearance it greatly resembles those constructed in France upon the plan of Woolf's apparatus; but the principle of its operation is totally different, the object being rather to cause a great economy in the consumption of fuel, than to obtain spirits of any required strength at a single operation. The heat absorbed in the conversion of a given weight of water into steam, exceeds greatly that which is required to raise its temperature to the boiling point; a pound of water converted into steam raising six pounds of water to the point of ebullition. The heat thus developed varies in different liquids, but is in all cases considerable; and as distillation is ordinarily conducted, this heat is not merely lost, but occasions a considerable additional expense, from the great quantity of water required to reduce the vapour to the liquid state. To obviate these two sources of loss, the patentee has contrived his apparatus, so that one portion of liquid formed into vapour shall be reduced to the liquid form by another portion of liquid, which is evaporated by the heat given out in the condensation. But to convert a fluid into steam, not only a certain quantity of heat is required, but the heat must also be of a certain intensity; thus, although a pound of steam at 212°, would raise six pounds of water to the boiling point, it would convert no portion of it into steam, as the moment the water had acquired the heat of the steam, it would receive no further portion of heat from it; but if the steam is formed under a pressure exceeding that of the atmosphere, its heat, as indicated by the thermometer, is increased, and consequently it will continue to impart heat to a liquid which has attained the boiling point under a less pressure than the steam employed to heat it. Upon the combination of these two principles, Mr. Stein's apparatus is constructed. Nos. 1, 2, 3, and 4, are four oblong elliptical vessels or stills, two of which are shown in section; the lowermost halves are enclosed in casings *a a*, forming thereby steam chambers *b b*; each still has a vertical pipe *c c c c*, terminated by a double passage cock *d d*, one passage opening into the pipe *e*, which leads to the worm tub, whilst the other opens a communication from one still to the steam case of the next still, by means of the curved pipes *f f f*; that from the still 1 leading to the steam case of still 2, and so on in succession. The stills are charged from the pipe *g*, the quantity admitted being regulated by the floats *h*; each steam case communicates by the pipes *l l l l* (which are furnished with cocks) with the pipe *k* proceeding from the boiler. From the lower part of the steam case proceed pipes *m m*; that from still 1 leads to the cistern, which furnishes the steam boiler with hot water, whilst the others may either communicate with one common main *n*, leading to a refrigerator, or they may each communicate with a separate refrigerator. From the upper part of each steam case proceeds a pipe (shown at 3 and 4) which communicates with a gauge pipe *p p*, and terminates in a syphon barometer *q q*. *r r r r* are the man holes to each still; *s s s s* the discharge pipes to the stills, the steam cases being emptied by opening cocks in the pipes *m m* leading to the main *n*. The operation is as follows:—The stills being charged, and the cocks *d* being open to *e*, the steam is admitted to each case by the pipes *l l* leading from the steam pipe *k*, and is rapidly condensed in the steam case, the air escaping by a pipe not shown in our drawing. When the liquor in the stills has nearly attained the boiling point, the steam is shut off from all the cases except that of 1, and the cocks *d* are opened to the pipes *f*, and the main *n*, being cleared of the condensed water, the cocks on *m* of 2, 3, and 4 are closed. The steam from the boilers (which is under considerable pressure) continues to flow into the case 1, and by the heat given out to the liquor in the still, causes it to boil; the vapour passes into the steam case

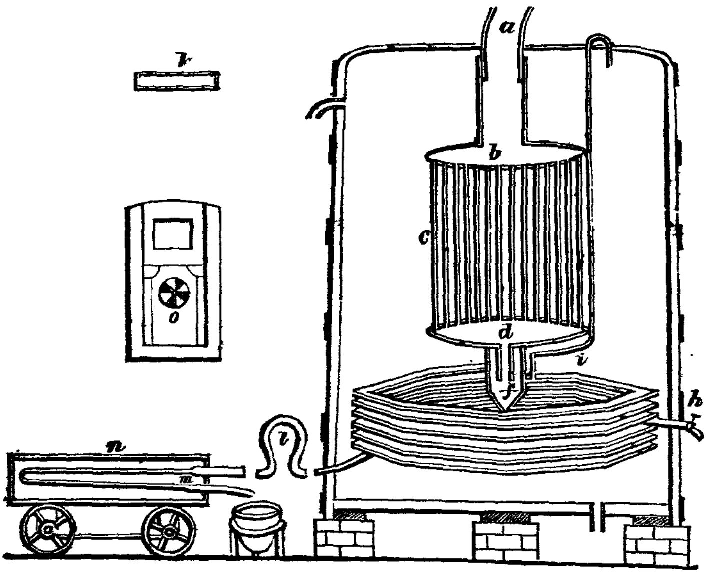
of 2, and the liquor in 2 condenses the steam in 1, until a common temperature is attained; then the steam from 1 being no longer condensed, and continuing still to receive heat from the boiler, its pressure, and consequently its temperature, increases, and it again gives out heat to the liquid in 2, which causes it



to boil. The vapour from 2 then passes into the steam case of 3, where the same process ensues, and which is subsequently repeated under the still 4, the steam from which passes by the pipe *e* to the condenser. As soon as the liquids in 2, 3, and 4 begin to boil, the cock on *m* must be partially opened to allow the condensed spirit to pass by the pipe *n* to the refrigerator; yet always

retaining a certain portion in the steam case, the height of which may be ascertained by the gauge pipe *p*, whilst the barometer *q q* will indicate the pressure of the steam in each steam case. The proper pressures will be best obtained by observation, as it will vary in different liquors during the distillation. The person conducting the process must, therefore, pay great attention to the barometer; and to enable him to do this with facility, the gauge pipes and barometer are all ranged in a cluster at the centre of the apparatus. By this mode of distillation, it will be seen that the latent heat of three-fourths of the liquid evaporated is saved, which produces a corresponding saving in the article of condensing water.

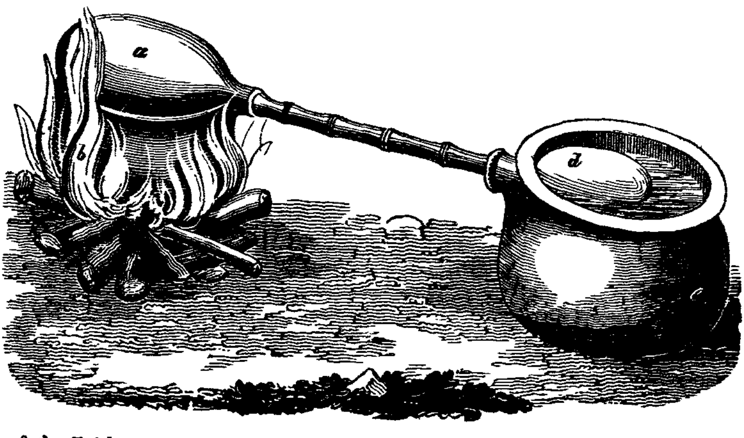
In Mr. Williams's apparatus for distillation, for which he obtained a patent about the year 1821, the improvements projected are comprised under the following heads; viz. an enlarged capacity of the still head, to cause a separation of the aqueous vapour by condensation, previous to its passing over the neck of the still into the spirit condenser; in the employment of numerous small vertical tubes, surrounded with cold water, to increase and accelerate the condensation; in the adaptation of a peculiarly constructed "cooling worm," by which it is conceived the quantity of spirit will be increased, by preventing evaporation in its progress to, and when in the receiver; and in the employment of refrigerating saline mixtures, for the more effectual cooling of the spirit



in warm climates, or in warm weather. In the body of the still (that part where the vapour is generated) there is no improvement proposed, but an enlarged capacity of its globular head, to cause the watery particles to fall back into the still; this part of the apparatus we have omitted in our diagram, as it requires no additional explanation; the engraving, therefore, relates wholly to the apparatus for condensation. *a* is the termination of the neck of the still, which conveys the vapour into the "upper drum" *b*, whence it is divided among a number of small vertical tubes *c*, which the patentee says, should not exceed three-fourths of an inch in their interior diameter. As the tub inclosing this apparatus is filled with cold water, the condensation immediately commences in the upper drum, and is completed in its subsequent progress through the vertical tubes, and the "lower drum" *d*. From thence the fluid runs

down a central neck *e* into the trap *f*, from the upper part of which trap it enters the cooling worm *b*. It is evident that the trap *f* is, in working, always partly filled with liquid; and the neck *e* being immersed therein, any vapour which may have escaped condensation can pass no further. The trap *f* has a funnel-shaped bottom, from which a pipe *h* passes through the coils of the worm, and through the side of the tub, where it is furnished with a cock for the purpose of drawing off any impure spirit which may be separated from the wash in the first stage of the process, and to discharge what may remain in the trap when the process is over. To the trap *f* is also attached another pipe *i*, called the safety pipe, for the purpose of allowing the egress and ingress of atmospheric air from and to the condenser, to prevent both pressure and vacuum therein. The coils of the cooling worm are made octangular; the worm itself is made flat, and of considerable breadth; a transverse section of it is exhibited in the separate figure *k*, which shows it to be in the form of a parallelogram, whose longest sides are four inches, and its shortest half an inch wide. This octangular worm, after making six complete turns, assumes a circular shape, and diverges off to pass through the side of the tub; at its end outside the tub, which is made a little tapering, is fitted, and is to be occasionally applied, a crane-necked pipe *l*, which pipe may be elevated or depressed at pleasure, for the purpose of keeping three or more of the coils of the worm full of liquid. This crane-necked pipe is intended to be applied in hot weather, or hot climates, to cool the spirits more effectually, and prevent their evaporation, by subjecting the same in a greater degree to the effect of the cold water in the worm tub. An additional apparatus, to be used in hot climates, of undoubted utility, is likewise recommended by the patentee, and claimed by him as his invention. It consists of another pipe *m*, into which the discharging end of the crane-necked pipe is made to enter; and which pipe, after passing the end of the trough *n*, is made of a very broad, flat shape, and running the whole length of the trough (which may be of any extent); it is then to return by a very slight descent, so as to run back very gently into the funnel of the pipe which conveys it into the receiver. The trough *n* is to be filled with Glauber's salts and nitre, or any saline mixture capable of producing intense cold, for the more effectual cooling of the spirit. The trough may be placed upon wheels and axles, for the convenience of bringing it to and conveying it from its required situation.

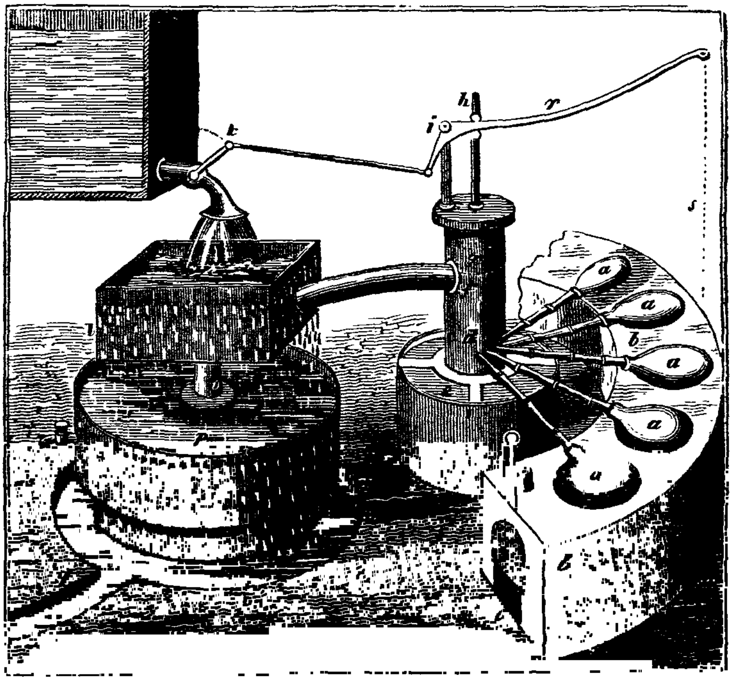
Distillation is very commonly practised in India; and although the apparatus is of the most simple (not to say rude) description, the products are generally of such excellent quality as to render the process deserving of the consideration



of the British manufacturer to discover the cause. The still commonly used by the natives of Ceylon is represented in the above cut. It is constructed

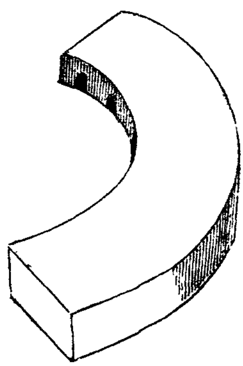
wholly of earthenware, excepting the tube of communication between the alembic and the refrigeratory, which is of bamboo. *b* is the body (or boiler) of the still; *a* is the capital, luted with clay to *b*; *c* is the bamboo tube, which conducts the vapour into the receiver *d*, where it is condensed by being immersed in the vessel of cold water *e*. It is with this rude apparatus, (according to Dr. Davy,) that the Singalese distil in the open air that fine spirit *arrack*, which is obtained from toddy, the fermented juice of the cocoa nut.

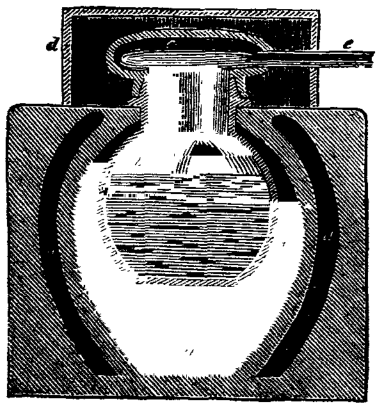
The editor of the present work, having a few years back had his attention called to the state of the arts and manufactures in Ceylon, and of the implements connected therewith, with a view to the improvement of the same, published a series of papers on the subject, in a periodical work which he at that time conducted, suggesting such alterations as seemed to him practicable with the simple means and resources at the disposal of the natives; and the Ceylonese still, just described, appearing to him to possess considerable merit, he proposed the following modification of it, in which, whilst the best features of it are retained, it is rendered in some respects more efficient, fuel and labour are economized, and by a simple method of combining several small stills, an apparatus is constructed adapted to operations on a more extended scale. *a a a a*



are the heads of a series of earthen boilers, of the kind described above, but instead of being exposed to the air, they are set in a close furnace *b b*, built of clay, or of the same materials with which their pottery is formed. This furnace is proposed to be built in a circular form, to any convenient extent, so as to surround wholly or partially the other parts of the apparatus; it is for this reason shown in the drawing as broken away, after being extended sufficiently to allow of five vessels being fixed therein. The curved figure of the furnace is given to it chiefly with the view of affording a convenient means of connecting the bamboo tubes which conduct all the vapours from the several

stills into the cylinder *d*. This cylinder is fixed firmly in a closed vessel *e*, which serves both as a recipient for the condensed liquid, and as an enlarged chamber for the vapours. On one side of the cylinder *d* there is an oblong aperture, made longitudinally for the egression of the vapours, which is covered by a light piston, so that when the vapours have attained but a very little more elastic force than is sufficient to overcome the pressure of the atmosphere, this piston is lifted, which uncovers the aperture to a certain extent, and permits the vapours to pass through a large bamboo tube of communication into a thin metal refrigerating box *l*; this metal box is supported by a strong tube *o*, fixed into the close recipient *p*, the tube being open to both. On the top of the cylinder is fixed a vertical standard, the upper end of which becomes the fulcrum to a lever crank *i*. To one end of this crank is jointed a rod or stout wire, which connects it to the handle of the water valve *k*: the other arm of the crank lever passes between antifriction rollers on the piston rod *h*. It will be manifest by this arrangement, that in exact proportion to the volume of vapour that escapes from the cylinder, will the precise quantity of water necessary to condense it be showered down upon the refrigeratory; and this is done uniformly and according to circumstances, without any attention on the part of the distiller. By the elevation and depression of the piston rod *k* also, the long arm *r* of the lever crank may, by means of a cord *s*, be made to open a sliding door or damper to the furnace, by an arrangement for this purpose omitted in the rough sketch. As it is objectionable to leave the still-heads exposed to the air, by which a portion of the vapour becomes condensed and runs back into the still, it is proposed to enclose them with a cap of wood or pottery, like that delineated in the margin above, which will envelope them in a heated atmosphere. To prevent the escape of the heat through the clay walls of the furnace, they are made double, with a stratum of charcoal between, as represented in the annexed sectional view,

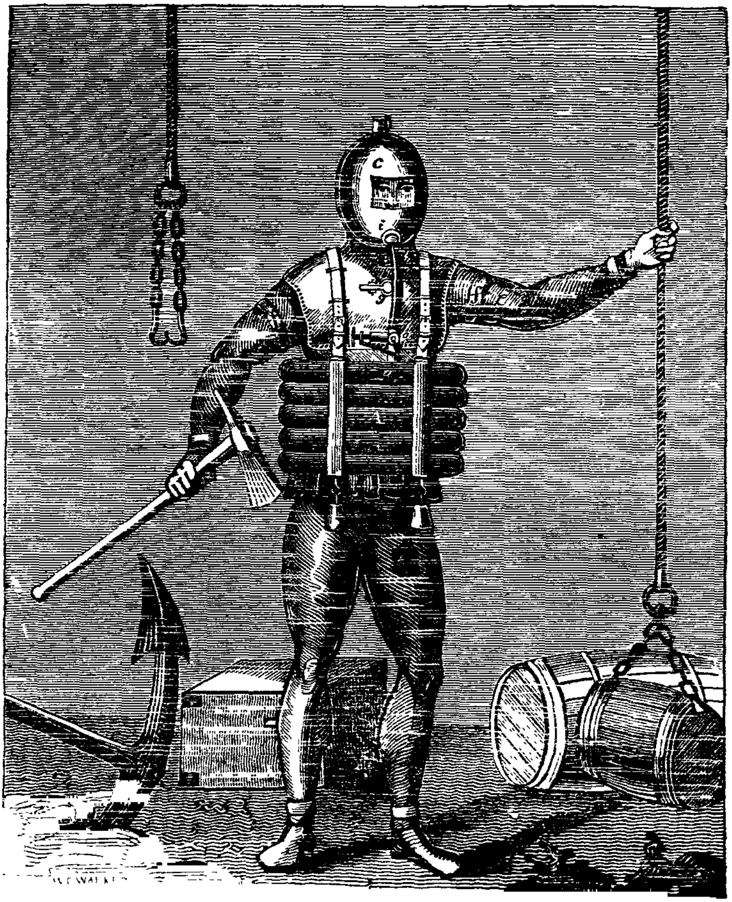




in which *a a* represents the strata of charcoal imbedded in the surrounding clay; *b* the boiler; *c* the head, luted to the boiler enclosed in the box *d*, through an aperture in which the neck *e* passes, that conducts the vapour to the cylinder; the cavities round the boiler *f f* are for the heated air, and *g* the hearth, on which the wood is thrown at one end of the furnace.

DIVING APPARATUS. Contrivances for the purpose of enabling persons to descend and to remain below the surface of the water for a great length of time, to perform various operations, such as examining the foundations of bridges, blasting rocks, recovering treasure from sunken vessels, &c. The apparatus most commonly employed for this purpose is the diving bell, the invention of which is generally attributed to Dr. Halley. These machines have been variously modified, but are now ordinarily made in the form of an oblong chest, open at the bottom. It is made of cast iron of considerable thickness, and has several strong convex lenses set in the upper side or roof of the bell, to admit light to the persons within. It is suspended by chains, hooked to strong staples in the upper part of the bell, and which chains are passed round

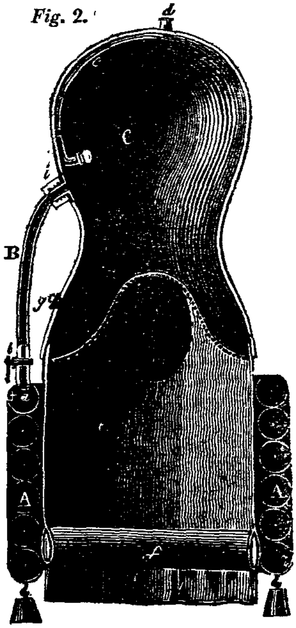
a windlass supported upon the sides of two lighters or barges, so that the bell can be raised or lowered, upon signals to that effect from the persons within the bell, who are supplied with fresh air by means of a flexible hose passing under the lower edge of the bell, and connected with a set of forcing pumps placed in the barges. The air which has been respired being heated, rises to the upper part of the bell, whence it escapes by a cock An apparatus has also been devised to enable a person to quit the diving bell, and remove to a considerable distance when requisite, and still to receive the necessary supply of air. It consists of a copper helmet, fitting water-tight to the shoulders of the wearer, and furnished with a mouth piece, to which is attached a flexible hose, reaching under the bell; but recently a patent has been obtained by Mr. W. H. James for a somewhat similar apparatus, by which a diver can carry on the necessary operations independently of a diving bell. The diver is attired with a portable vessel (placed around and adapted to the figure of his body,) which is filled with condensed atmospheric air; and by means of a simple arrangement of pipes, and judiciously constructed valves, he is enabled to supply himself with fresh air for respiration during the time he is under water. In the



two accompanying figures, the letters in each refer to the same parts. *Fig.* 1 gives a front view of the diver fully equipped in the apparatus, and supposed to

be engaged in recovering from the deep a variety of sunken property; and *Fig.* 2 gives a section on a larger scale, for the better understanding of the several parts. A is the vessel to contain the condensed air, which is to be filled by means of a condensing air-pump; it consists of a series of strong metallic tubes, or of one continuous tube, coiled elliptically round the body, and connected together by bands, to which straps are attached to secure it in its position. At *a* is a valve opening inwards, through which the air is to be forced by means of a condensing pump, until it has acquired the required degree of density, which will, of course, be determined by the time it is proposed for the diver to remain under water. B is a tube made of caoutchouc (or Indian rubber), for conveying the air into the water-tight helmet C, by means of a valve so contrived as to be completely under the control of the diver. This helmet may be made of any water-tight material, but thin copper is recommended; it is provided with a strong plate of glass in front, to enable the diver to see surrounding objects Inside the helmet is a flexible tube *c*, with a mouth-piece at the end, which comes near to the mouth of the diver; through this the air is discharged from his lungs, and passes out through a valve *d* in the top of the helmet. At the lower part of the helmet, and round the breast, back, and shoulders, a water-proof garment *e* is attached, fitting closely round the body of the wearer, and made fast by elastic bandages *f*. To secure the diver from being inconvenienced by the pressure of the air within the helmet becoming too great, a safety-valve is introduced. Notwithstanding the weight of the apparatus (amounting perhaps to 50 lbs.), the density of the water at great depths would render the body of the diver too buoyant to keep on his legs and execute his work; in these cases it will become necessary to attach weights to his person, capable of being easily removed, if desired; some are therefore shown in the figures as attached to the apparatus; these, however, it may be desirable to place lower down his person, about his legs and feet. The same apparatus (divested of the weights) may be employed with safety and advantage in mines and other places filled with deleterious gases.

Fig. 2.

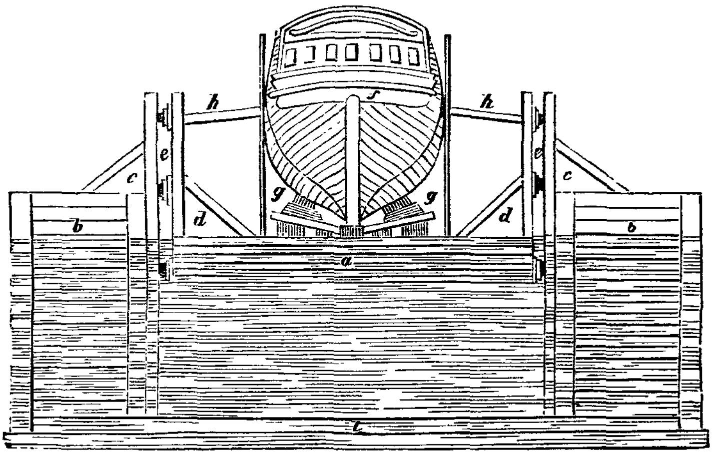


DOCKS. Enclosed excavations or basins, formed for the reception of shipping. There are two descriptions of docks, viz. wet docks, and graving or repairing docks. Wet docks are extensive basins formed adjacent to rivers and harbours, with which they are connected by means of a lock, furnished with gates at each end, so that vessels remain afloat at all times of the tide. They are usually surrounded with warehouses, for the purpose of loading or discharging vessels. The wet docks in this country are numerous and extensive, and have proved highly beneficial to its commercial interests; as in these ships lie in perfect security from storms and depredation, their cargoes are taken in and delivered with the utmost dispatch, and the navigation of the rivers is freer from obstruction. The town of Liverpool, which, from the badness of its harbour, resorted to the construction of wet docks in 1708, has at the present day a range of them in front of the town, and along the banks of the river Mersey, extending more than two miles in length, and which, from their concentration in one spot, form the most striking display of the kind that can any where be met with. Hull, Bristol, and Leith, have successfully emulated this example. Although London was without the conveniences of wet

docks until the commencement of the present century, it can now boast of several, some of which exceed in magnitude any in other parts of the kingdom. The first of these undertakings was the West India Docks, for the accommodation of the West India trade, erected under an Act of Parliament passed in July, 1799. The great basin is 420 yards in length, and 230 yards in width, covering an area of twenty acres. A basin of nearly three acres connects it with the river. The warehouses are most noble buildings; the tobacco warehouse is the most spacious erection of the kind in the world, being capable of containing 25,000 hogsheads of that article, and the vaults underneath, as many pipes of wine. This single building under one roof is said to occupy upwards of four acres of ground. These docks were opened in 1805. The London Docks were begun in 1800, and completed in 1805. The principal basin is 420 yards in length, and 276 in width, giving an area of 25 acres. The principal range of warehouses occupies a superficies of 120,000 square yards. The first stone of the East India Docks was laid in March 1825, and the first vessel entered them in August 1826. The dimensions of the dock for unloading inwards are 1410 feet in length, and 560 in width; the dock in which vessels load outwards is 780 feet long, and 520 feet wide; and the entrance basin, which connects them with the river by a lock, is 2¾ acres in extent. The lock is 210 feet in length, the width at the gates 48 feet in the clear, and the depth of water at ordinary spring tides 24 feet. The warehouses at these docks are of trifling extent, the principal part of the cargo of vessels unloading here being conveyed in vans direct from the ships to the East India Company's warehouses, situated in various parts of the city of London. Besides these principal docks just enumerated, there are various others in the port of London, which our limits will not allow us to notice.

Graving or Repairing Docks are excavations sufficiently large to admit one or sometimes two vessels for the purpose of being repaired. At the entrance is a pair of gates, forming an angle outwards or towards the river. When it is required to dock a vessel, the water is admitted by means of sluices, and when it has attained the same level within the dock as without, the gates are opened, and the vessel hauled in over a range of blocks previously laid on the floor of the dock; the gates are then shut, and the vessel, being steadied by shores or props placed against the side of the dock, as the tide recedes, settles upon the blocks. At low water the sluices are shut, and the water (if any) remaining in the dock is pumped out, so as to leave it perfectly dry, and to allow any part of the vessel's bottom to be examined and repaired. When the soil is of an unfavourable nature for excavations, as also with a view to avoid the delay which often occurs from ships being able only to enter some repairing docks or to leave the same at the height of the springs, a contrivance, called a floating dock, has been proposed, in which vessels may receive the necessary repairs. Various constructions have been offered for this purpose. The engraving on the following page represents a design for a floating dock, by Mr. Edward Clark, of New York, civil engineer. This dock is proposed to be constructed by forming a float of timber to constitute the bottom of the structure, and which, by its buoyancy, shall support a vessel within the dock with its keel above the surface of the water. To attain this end the float is made in the form of a hollow box, composed of strong logs firmly jointed together and caulked, so as to render it water-tight. The capacity of the hollow part must be such that, when exhausted of water by means of pumps, it shall be sufficiently buoyant to sustain itself with its load. *a* represents the float; *b b* the piers, forming a recess to steady and secure the float; *c c* perpendicular supports and braces appended firmly to the piers; *d d* also supports appended firmly to the float, so as to allow by means of the rollers *e e* of the easy and steady ascent and descent of the float conformably to the motion of the tides and waves, and also of sinking and raising the float in the same place; *f* the stern of the vessel; *g g* bilge blockings; *h h* braces, all for supporting and steadying the vessel in an upright position; *i* timbers framed into the piers, forming a bed for the support of the float while sunk. The float *a* is supplied with valves and pumps (not shown in the engraving); and if it be required to float the vessel *f*, nothing

more is necessary than to open the valves, when the float, being previously ballasted, will fill with water and sink to its bed. The vessel *f* being now removed, and another made to occupy its place by means of guides, the valves are to be closed, and the pumps put in motion, and when a quantity of water has been displaced from the float equivalent to the weight, she will be elevated entirely above the water, and placed in a most favourable situation to undergo



repairs. A float of this description, for use in sea water, would require to be coppered externally, and occasionally to be filled with some other saline fluid, or with fresh water, to preserve it from worms. The Committee of the Franklin Institution at Philadelphia, to whom this invention has been submitted by Mr. Clark, state, in their report thereon, that the main objection to docks of this description, made sufficiently capacious for vessels of large dimensions, and for the operations to be carried on in repairing them, is the unequal pressure to which their bottoms must be subjected by the weight of the vessel upon them, and the upward pressure of the water. They are aware that, by judicious shoring, much of the weight of a vessel may be distributed over the bottom; this, however, although it would lessen the objection, would not remove it. Ships, although constructed in a shape and braced in a manner calculated to render them stable, undergo in nearly every instance a change of form after they are launched; to this change of form the float in question would be much more liable, inasmuch as its flat surfaces are less calculated to resist the effects of the pressure to which they are subjected.

DODECAGON. A regular polygon of twelve sides.

DODECAHEDRON. A solid, having twelve equal and similar sides or faces, each of which is a regular pentagon.

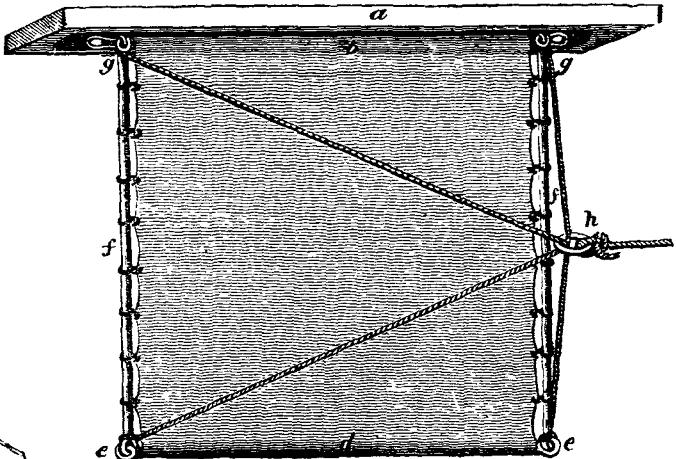
DOVETAIL is a term implying a mode of connecting two pieces of wood or other substance together by means of cutting their extremities into the form of a dove's tail, and interlocking them so that they cannot be separated in the direction of the strain without breaking the materials asunder. Sometimes a solid piece dovetailed at each extremity is employed to connect two other pieces or parts together, by entering morticed cavities in the latter.

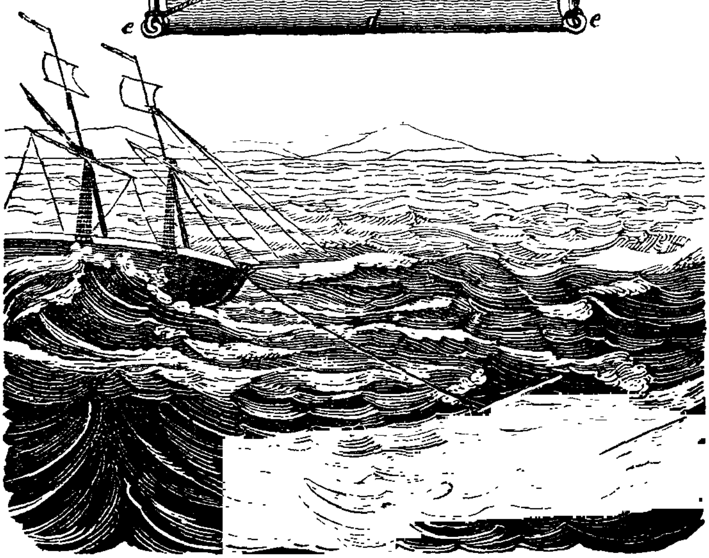
DOUGH. The paste formed by kneading flour and water together in the preparation of Bread, which see; also Kneading.

DRACHM, or DRAM. A weight consisting of the sixteenth part of an ounce avoirdupois, and the eighth of an ounce in apothecaries' weight.

DRAG SHEETS. The name given to a contrivance for lessening the drift of vessels in heavy gales of wind, for which Mr. Burnett obtained a patent in 1826. The current caused by the action of the wind extends but a

few feet below the surface, even in the heaviest gales; and if a body be sunk to a considerable depth it will remain nearly stationary. Dr. Franklin, aware of this fact, recommended vessels encountering adverse gales in the open ocean, instead of lying to, to form a kind of floating anchor by attaching a stout hauser to four bridles from the four corners of a sail, the corners being distended by spars, and then lowering the sail into the sea with sufficient weight to sink it. The effect of it will be considerable in retarding the pro-





gress of the vessel astern. Another well-known fact is, that any substance floating upon the water, prevents, in a very great degree, the waves from breaking; and fishermen and sailors who have taken to the boats upon a vessel, frequently make them fast with some scope of rope to a spar, which they throw overboard, which breaks the force of the waves, and allows the boats to ride in comparatively smooth water. Mr. Burnett's invention is a combination of these two plans, as will be perceived from the annexed representation of it. The upper figure represents the drag sheet, viewed a little in

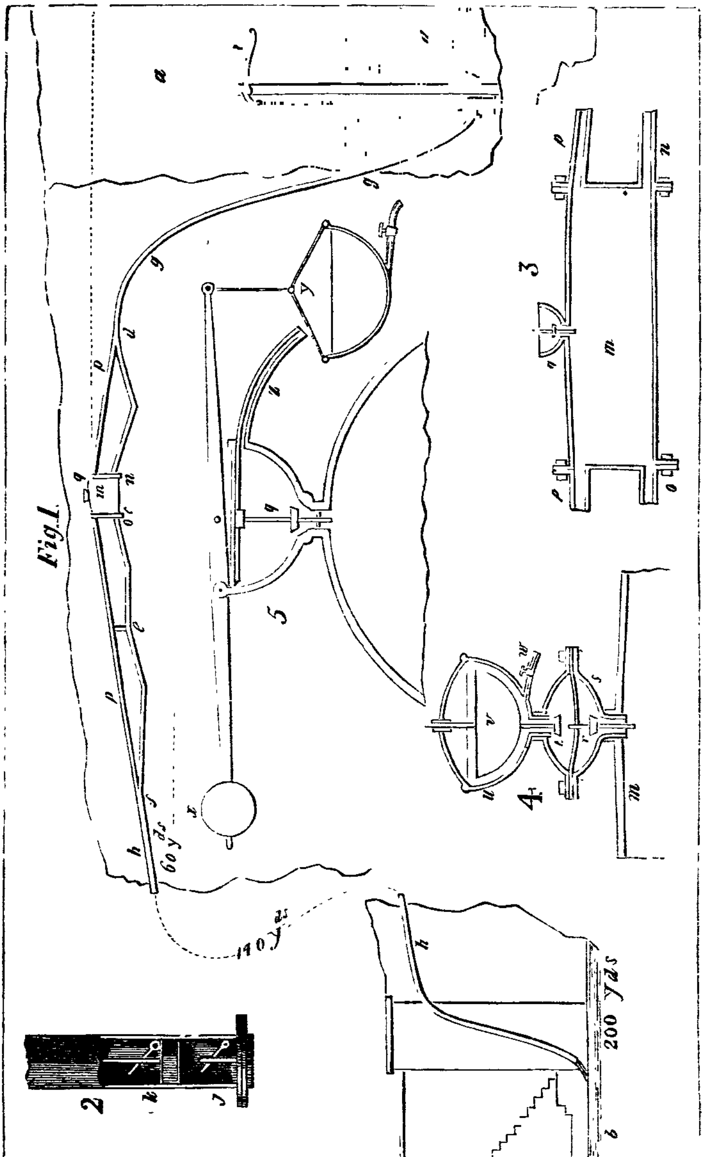
perspective; *a* is a plank hollowed out underneath, so as to form a cavity of sufficient dimensions to receive the remainder of the apparatus when rolled up. When in use, this plank forms the float for the rest of the apparatus; appended to it, and sunk in the water *b*, is a circular bar or rod of metal, firmly fixed at the extremities to the float, within the cavity before mentioned; round this bar the upper side of a square piece of sail-cloth *c* is fastened; the lowermost side is in like manner secured to another metallic bar or roller *d*; the extremities of *d* are formed into rings or eyes, which are thereby hung upon hooks attached to the uppermost bar *b*; a series of eye-hooks, like the one shown in the margin (at *i*) sliding upon the rods *f* are then employed to stretch the canvass *c* tightly out between them. The frame thus completed, a rope or chain is attached to each corner of it; one from *e* to *g* on the one side, and another chain in the same manner on the opposite side; both these pass through a ring *h*, as represented, which ring is attached to a hauser or cable, that is made fast to the bow of the ship. By this arrangement the heaving of the vessel, or of the drag, by the undulatory motion of the waves, allows the ring to traverse up and down the chains, preserving thereby the perpendicularity of the drag, and consequently producing the utmost resistance to its passage through the water.

DRAGON BEAMS are two strong braces, supporting a breastsummer, and meeting each other on the shoulder of the king-post.

DRAGON'S BLOOD. A red coloured resin, imported from the East Indies. It is insoluble in water, partially so in alcohol, but dissolves readily in oils: the solution imparts a beautiful red stain to hot marble.

DRAINING, in Agriculture, the process of drawing off the water from bogs, marshes, and lands liable to be flooded by excessive rains, by means of drains or trenches cut to some depth below the surface, which drains serve to collect the waters and convey them off to some lower level. Until the middle of the last century little attention was paid to the draining of lands. The first person who treated the subject systematically appears to have been Dr. J. Anderson, of Edinburgh, who showed that the origin of swamps and morasses lay in the waters, attracted from the atmosphere by the summits of hills and mountains, percolating through the various porous strata of which they are composed, until they arrive at a stratum of clay, which, being impervious to the waters, they stagnate and accumulate, until by their increasing upward pressure they force their way through the soil of the valleys and lowlands at the foot of the hills, and form bogs and marshes. The principle of his system of drainage consists in intercepting the waters in their progress below the surface from the hills to the low grounds, by a trench running along the base of the hill, and extending to the substratum of clay, which impedes the progress of the water; from this trench a drain is cut, to convey the waters to the nearest channel that will carry them away. Mr. Elkington, about the same period, appears to have paid great attention to the subject in England, and for various improvements which he introduced in the practice, received from Parliament the sum of 1000*l*. In cases where the top soil is of considerable depth, and no water therefore rises into the ditch, after cutting five or six feet down, both Mr. Elkington and Dr. Anderson recommend to bore with a proper auger until the clay be reached, when the water will rise through the holes into the trench. These trenches should be made narrower as they descend, by spades of a proportionate size, but the lowest part ought to be more contracted than any other, so that the shoulders or edges of it may support stones or faggots, in order to cover the whole at a small expense without obstructing the currents of water. In many places hollow bricks or ridge tiles are substituted for stones or faggots, as being cheaper. When the land to be drained consists of a long level tract, without sufficient fall to carry off the water from the reservoirs or pits into which it is conveyed by the drains, or when there is a rising ground or an embankment between the drained land and the level which is to convey the

water off, it must be elevated mechanically; for this purpose pumps, driven by windmills, are very extensively employed in Lincolnshire. Where there is sufficient outfall, water may also be conveyed over an intervening obstacle by



means of a syphon, provided that the height of the syphon do not much exceed 20 feet; but one objection to this method consists in the interruption to which the action of the syphon is liable, from the extrication of the air which all

common water contains, and which begins to separate from that fluid as it rises under diminished pressure in the short leg of the syphon, till at length the angle of the syphon is filled with air, and the current of water is interrupted. To remove this defect, Mr. Cowen, of Carlisle, places a box at the upper angle of the syphon, into which all the air separated from the water rises; and the application of a forcing pump for a few minutes once or twice a day drives the air out of the box into the atmosphere. *Fig.* 1 represents Mr. Cowen's plan applied to the draining of a quarry. *a a* represent a part of the quarry; *b* a level lower down than the bottom of the quarry, which, in this case, is 200 yards off where the water is to be discharged; *c* the highest ground over which the water is to be conducted; *d*, *e*, and *f*, three distinct rises, over which the pipes pass (they are further apart than here shown); *g g h h* the lead pipe, composing the two legs of the syphon; *i* a common forcing pump, fixed below the surface of the water, having a hinge valve at *j*, *Fig.* 2, and an open working box, with a similar valve *k*. These valves are opened by the force of the water flowing through the pump in its passage to the syphon; *l* the working handle of the pump; *m* is a close iron receiver, shown larger in *Fig.* 3, having inserted at the end *n* the ascending leg of the syphon *g*, and at the other end *o* the descending leg *h*; at the upper side of both ends are inserted two small air pipes *p p*, joining with the syphon pipe at the highest bends, as shown at *d*, *e*, and *f*, with a regular slope into the interior, to allow the air to ascend into it; *g* is a small valve fixed at the highest point of the receiver, to allow the whole of the air to escape through the valve when the water is forced up by the pump; for this purpose the pump *i* and the pipe *g* must be capable of supplying the water quicker than the pipe *h* will carry it off.

Directions to be observed in laying the syphon to suit different situations.—First, in laying the pipes of the syphon, it is necessary to give them a regular slope, to admit the air to pass forward into the receiver, or to the highest bends, which must have either an air receiver to each bend, or a pipe inserted to convey the air to a general receiver. Second, when sufficient descent can be obtained on both sides from the air receiver, no air pipes will be required. Third, in situations where it may be necessary to carry the pipes over more than one elevation, and the second exceeds the height of the first, a separate receiver will be required for each elevation. On this construction, viz. with more than one receiver, it is necessary to adopt the following expedient for closing the valves in succession as the air is expelled from each receiver. *Fig.* 4 is the lower valve in the receiver *s*, which is opened by the force produced by pumping, and the air escapes; *t* is an inverted valve, with a float *v* fixed upon the valve spindle in the centre of the cup *u*. While the air only is expelled, the inverted valve will remain open; but when the water is forced out and fills the cup, the float will rise and close the valve at the same time; thus the water being stopped from flowing out, will be forced forward to any number of receivers in succession. *w* is a very small outlet pipe, inserted into the bottom of the cup *u*, through which the water escapes slowly; as the cup is emptied the float is lowered, and the inverted valve again opened—a position necessary to allow the air to escape at the next pumping. Another method for closing the valve is shown at *Fig.* 5. *q* is a valve placed in a cup, as shown in *Fig.* 1; on the cup is mounted a lever, with a counterweight *x* at the one end, and a small pendant receiver *y* at the other end; *z* is a conducting tube inserted into the edge of this cup, to convey the overflowing water into the receiver, which, as it fills, loads the valve and prevents the escape of the water, and thus forces it forward, as before described, to any number of receivers. The preceding account of this valuable improvement in the art of draining, by means of the syphon, is extracted from the original description of it by Mr. Cowen, in the *Transactions of the Society of Arts*, for the communication of which the Society awarded him the gold Vulcan medal. In the 45th volume of the *Transactions* are some interesting details of his experiments.

DRAUGHT. The depth of water necessary to float a ship or other vessel. For the draught of carriages, see RESISTANCE.

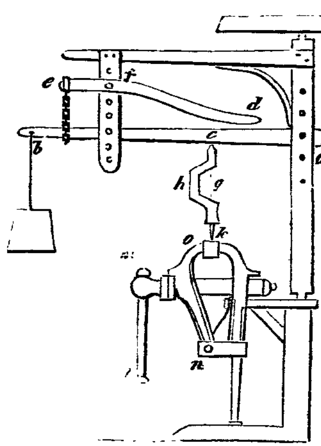
DRAWBRIDGE. A bridge thrown over a ditch or ravine, which may be

drawn up or let down at pleasure, one of its ends serving as an axis or joint for that purpose, while the other is connected by means of chains to two strong levers, called plyers, which are framed together with other timbers in the form of a cross, and are supported by two jambs, on which they swing. Bridges of this kind are most common in fortresses, to cut off communication with the surrounding country. In canal navigation, and in wet docks, swing bridges that turn horizontally upon one end as an axis have almost wholly superseded drawbridges.

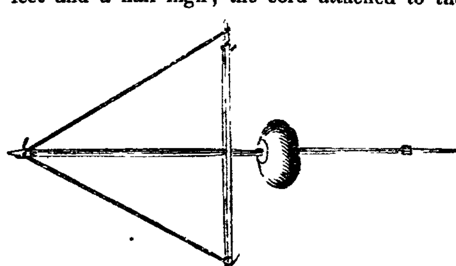
DRIFT, in Mining, a passage dug under the earth, betwixt shaft and shaft, or turn and turn.

Drift, in Navigation, the angle which the line of a ship's motion makes with the nearest meridian, when she drives with her side to the winds and waves, and is not governed by the power of the helm. It also implies the distance which the ship drives on that line.

DRILL. An instrument for boring holes in metals and other hard substances. It usually consists of a straight piece of steel, one end of which is formed into an angular point, and the other into a blunted round point, for inserting into a hole in a steel breast-plate, which is worn by the workman whilst operating with the instrument, in order that he may steadily press the point into the work, while he, at the same time, turns it backwards and forwards by means of a bow and cord, the latter being passed around a small pulley fixed about the middle of the drill. Sometimes drills are fixed to braces or stocks for the purpose of drilling. For boring large holes in metal, smiths and engineers employ a very convenient arrangement of levers for applying pressure to the drill, which is called a press-drill, and is delineated in the subjoined cut. *a b* is a lever of the second class, whose fulcrum is at *a;* the weight being applied at *b*, its efficacy is transmitted to the point *c*, in a ratio proportioned to the relative distances between *b c* and *e a*. As the pressure upon the drill often requires relieving, a lever *d e* is added, whose fulcrum is at *f*. The extremity of the shorter arm is connected to the lever *a b* by any convenient method; and when the workman wishes to release the brace *g*, he applies his power to the extremity of the longer arm by pulling down at *d*, which raises the shorter arm, and with it the lever *a b*, consequently the brace *g* is at liberty to be removed. In order that the work may be firmly fixed, it is usual to screw it fast between the chaps of a vice, as shown at *o l m n* in the cut.



The annexed cut represents an extremely simple and ingenious contrivance for drilling holes, used by the smiths in Ceylon. It is about two feet and a half high; the cord attached to the cross sticks is made of slips of hide twisted. The round weight to give momentum is of compact neiss, neatly cut. Any kind of borer can be fixed to the extremity of the wooden rod. The instrument is worked on the principle of torsion. The hole in the cross arms or handle, through which the spindle of the drill passes, is suffi-



ciently large to admit of it being slided easily up and down the spindle. Upon turning the cross a few times round the spindle, the cords become twisted in a corresponding degree round its upper part, and upon pulling the cross downwards, the cords in untwisting impart a rotatory motion to the spindle, which, by the impetus which the weight upon it acquires, is continued after the cords have become straight; and the cross being then slided up the spindle, the cords become twisted round it in a contrary direction; and by again depressing the cross, the spindle revolves the reverse way.

Drill, in Gardening and Agriculture, a small trench made in the ground, for sowing in it the seeds of vegetables.

DRILL HARROW. A small harrow employed in drill husbandry, for extirpating weeds, and pulverizing the earth between the rows of plants.

DRILL HUSBANDRY. A mode of cultivation in which the sowing of seeds in drills is adopted, instead of the more common method of broad casting. It is also called horse-hoeing husbandry, because the plants thus cultivated in rows admit being cleansed from weeds and earthed up by a machine drawn by one horse, and therefore called a horse-hoe. A great variety of machines are employed in this branch of agriculture. See Plough.

DRUG. A general name of commodities brought from abroad for the purposes of medicine, dyeing, tanning, and various other arts.

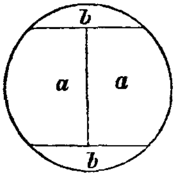
DRUG MILLS are machines used for triturating drugs; but as they are for the most part applicable to the grinding of other substances, they are described under the general head of Mills.

DRUM. A martial musical instrument in the form of a cylinder, hollow within, and covered at the two ends with vellum, which is stretched or slackened at pleasure, by means of cords with sliding knots. The cylinders are usually made of wood, but sometimes of brass. Kettle-drums are large basons or hemispheres of copper or brass, covered on their flat sides with vellum, which is fastened to the peripheries by circular rims of metal, provided with tightening screws for tuning them; they are usually played upon in pairs, and are chiefly used in the musical bands of cavalry regiments, or in oratorios, operas, &c.

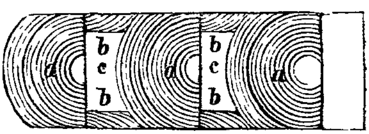
Drum is a term in machinery, applied to cylinders or barrels, around which endless straps, chains or cords, are passed, to communicate motion or power to other mechanism. When cylinders so employed are narrow in the direction of their axes, they are usually denominated *pulleys* or *riggers*.

DRY ROT. A term applied to that rapid decay of timber by which its substance is converted into a dry powder, which issues from minute tubular cavities resembling the borings of worms. On the causes of this decay numerous volumes have been written, and nostrums for its prevention or "cure" have been proposed without number, yet the dry rot continues to ravage our houses, and to destroy our ships. It has been said that moist and warm situations, where the circulation of the air is impeded, is the generating cause of this disease, and that the effluvia from timber so diseased will carry its effects to the circumjacent timber; and that any sort of wood, dry as well as damp, so exposed, will be soon destroyed. Timber once infected cannot be restored, and the only remedy lies in cutting away the diseased parts, to prevent the extension of the evil to the remainder; and to effect even the latter a free circulation of air must be admitted, and the parts be washed over with a strong solution of iron, copper, or zinc. Patents have been granted for various applications of the latter, as preventives of the dry rot, the distinguishing features of the processes therein employed consisting in first preparing the timber by a good steaming, or drying out of the sap, and afterwards injecting, soaking, or boiling the timber in a solution of copperas, or other metallic salt. The following observations on this important subject were some time since addressed to the editor by Mr. John Gregory, who is an experienced and observant shipwright; and as they appear to mark out clearly the true cause of, and to suggest a very simple remedy for, the evil, it is right to give them a place in this work. Mr. Gregory says, "Instead of squaring a piece of timber according to the usual method, by leaving the heart of the tree in the centre,

my plan is to saw it right down the middle, through the heart, into two equal parts, immediately after the tree is felled; and my reasons for this I will now endeavour to explain to the best of my ability. It is, I believe, a well-known fact, that a tree does not, literally speaking, *die* on receiving the final stroke of the axe, but that it continues for a long period afterwards to vegetate, though less vigorously. At length, however, the sap ceases to circulate, the pores become closed, and the juices of the tree thus shut up undergo decomposition, and lay the foundation of dry rot. It is well known that a man who dies in a full habit of body soon decays; the same effect takes place in a tree full of sap, unless we adopt the same method with respect to it as the Egyptians practised with the human body, viz. that of depriving it of all moisture, which process would give to our timber a durability almost everlasting. My mind has been long impressed with this idea, which has been confirmed by my having recently noticed that several of the timbers in a very ancient public building, which had been sawn originally in the manner I have proposed, were *perfectly sound*, although they had withstood the dilapidating hand of time for seven hundred years; while other timbers in the same building, which had not been so cut, but apparently squared out with the heart in the centre, were *perfectly rotten*. That the dry rot is certainly caused by the juices being enclosed in the heart of the timber, I have had frequent opportunities of observing during my long practical experience in the repairing of ships. In the frame of a ship in which such large quantities of timber are employed, I have uniformly noticed, First, that the decay commences in the run fore and aft, which is owing to the timbers being fitted so close together at the heels or lower ends. The evil being thus enclosed in the hearts of the timbers, and the air having no access to the exterior of them to carry off the moisture by evaporation, internal decay is the necessary consequence. I have sometimes witnessed these parts of the frame of a ship in such a rotten state as to have been justly compared by the workmen to a heap of manure. Secondly, those timbers in the midships that have been bored off with the outside planks are not so affected, which I attribute to the circumstance of the holes admitting a current of air through them, the destructive juices being thereby carried off. Thirdly, it frequently happens that the floor timbers of an old ship are found, on breaking up, to be nearly as sound as they were when first put in. Their preservation seems to be owing to the effect of the salt water which constantly laves over them, causing them to become in a manner pickled; or it may be, that the salt entering into the composition of the wood, the destructive effects of its natural juices are thereby prevented. Fourthly, the planks in the bottom, nearest to the timbers, take the infection first; and where the tree-nails are not close, the disease rapidly extends endways of the grain. Fifthly, those parts of the deck planks that lie *upon* the beams are those which are first infected with the rot, the cause of which is evident, as those parts that are *between* the beams are generally quite sound. Sixthly, in the beams of ships the decay usually commences in the internal parts, which is decidedly owing, in my opinion, to the erroneous method of preparing the timber, as before mentioned; but when timber, so prepared, is used, I would recommend, as the best preventive of the rot, that a few holes be bored through the beam fore and aft, and, what would still add to the benefit, to bore another hole lengthways of the grain, to meet those which are bored crossways. But the best preventive, I am confident, would be the adoption of my mode of preparing the timber, namely, to saw it lengthways right through the heart, by which not only much greater durability would be obtained, but great economy in the consumption of the timber, as well as a great increase of strength, which I will proceed to explain by reference to the annexed figure, which exhibits an end view or section of a piece of timber. Having procured a log of the shape required, first cut off the two slabs *b b*, and then divide the remainder *a a* into two equal parts. Being thus sawn through the heart, the air will rapidly absorb the juices, and such a seasoning may be soon effected as will, I have no doubt, completely prevent the dry rot. But my object in



this place is to show the economy of the plan in a mechanical point of view. By thus sawing a log through the middle, two timbers are immediately provided instead of one, and both of one precise mould. Thus when the pieces *a a* in the above figure are placed end to end, they will form two timbers exactly similar, as appears by the annexed figure. The expedition gained by this method of converting timber is obvious; every ship-builder is fully sensible of the difficulty he is often put to, and of the sad waste of time and labour often incurred in preparing two such timbers to match one another. It not unfrequently happens that the framing of a ship stands still for several days owing to this circumstance. The saving of time and labour is in consequence an important saving in the expense of building. I have also proved by experiment that this mode of sawing the timber down the middle confers great additional strength. From the same bough I cut two pieces of the same length and thickness; one of them I squared according to the usual plan, which I condemn, the other, according to my proposed method, leaving the circular sides, as shown at *a a* in the foregoing figures. The proportional strength of only one of the pieces I found to be as 25 compared to 27, the strength of the whole square timber; the strength of the two pieces, therefore, makes the difference of 50 to 27, or nearly double; in addition to which advantage, far greater durability will be obtained by the prevention of the dry rot. For the timbers of a 74-gun ship, logs of 22 inches diameter are usually employed; if these, instead of being squared, are divided according to my method, their strength and width of bearings for the planks will be fully adequate, and the little difference of strength may be easily compensated by two or three more timbers, for which there will be plenty of room, and the saving of expense will thereby be immense. By the most accurate calculations that I have been enabled to make, I find the saving in timber only to be full one-third. The annexed sketch represents a horizontal section of a small portion of a ship's side, with the arrangement of the timbers according to my plan. *a a a*, three of the ship's timbers; *b b b b*, the fittings made from the slabs before mentioned, which are uniformly of a suitable shape; *c c* are air passages, which serve effectually to carry off whatever moisture may remain in the timber, the hearts of the trees being exposed to the air. It will likewise be perceived that the circular form of the grain being retained, the strength of the timber is better preserved than if the logs were squared, as I have proved by the before-mentioned experiment. From long observation and repeated investigation I am indeed convinced that the *outside*, or younger part of a tree, is stronger, more durable, and more seaworthy, than the heart, notwithstanding I have daily witnessed the preference given to the latter, while the former has been used for fuel. In the repairing and breaking up of ships, it will be almost invariably found that the decayed planks have the heart of the tree, and the sound ones, not; it follows, therefore, that the present system of lining is very defective. To lessen the charge of carriage, it is not unusual to side the logs where the trees are felled. Now, if the trees were also sawn down the middle in the forest, an increased facility of removal would be acquired, and the timber would be seasoning, and probably be fit for use, ere it came into the dock-yard. The longer a tree remains whole after it is felled, the more sap it will contain, and the more rapid will be its decay. I have seen many trees that were sound when felled, decay from the heart outwards, owing to their lying a long time with their juices shut up in them. The dividing of the trees would have preserved them."



DUCTILITY. That property or texture of bodies which renders it prac-

ticable to draw them out in length, while their thickness is diminished. without any actual fracture of their parts.

DULCIFICATION, or DULCERATION, in Chemistry, the combination of mineral acids with alcohol, by which their caustic or corrosive qualities are diminished: thus we have dulcified spirit of nitre, dulcified spirit of vitriol, &c.

DULCIMER. A musical instrument, strung with about fifty wires, cast over a bridge at each end. It is performed upon by striking the wires with little iron rods.

DUODECIMALS, or CROSS MULTIPLICATION, is a rule used by workmen and artificers in computing their work. Dimensions are usually taken in feet, inches, and parts, omitting all those which are less than one quarter of an inch as of no consequence. Rule:—Set down the two dimensions to be multiplied together one under the other, in such manner, that feet shall stand under feet, inches under inches, and parts under parts; then multiply each term in the multiplicand, beginning with the lowest, by the feet in the multiplier, and set the result of each directly under its respective term, observing to carry one for every 12 from the parts to the inches, and from the inches to the feet. In like manner multiply all the multiplicand by the inches and parts of the multiplier, and set the result of each in one place, removed to the right hand of those in the multiplicand, and the sum of these successive products will be the answer.

Example. Multiply 6 feet 4 inches 3 parts by 10 feet 3 inches 9 parts.

	ft.	in.	pts.		
	6	4	3		
	10	3	9		
	63	6	6		
	1	7	0	9	
		4	9	2	3
Answer . .	65	6	3		

It should be observed, that the feet in the answer are square feet, but the numbers standing in the place of inches are not square inches, as might at first be supposed, but twelfth parts of square feet, each part being equal to twelve square inches. In like manner the number standing in the place of parts, or in the third place of figures, are so many parts of the preceding denomination; these, therefore, are square inches.

DYING. The art of tinging or imbuing various substances with different colours at pleasure. The principal application of this art is to fabrics of wool, silk, and cotton; but it is also applied to the colouring of leather, marble, ivory, and various other substances. We shall limit our description to the process of dying the first-mentioned substances. The simple colours employed in dying are mostly either of animal or vegetable origin; but although the number of possible dyes which might be obtained from these sources is almost infinite, the number employed in the regular manufactories of Europe is small, the infinite diversity of tint which is obtained being the result of the combination of two or more simple colouring substances with one another, or with certain chemical reagents. Of the great variety of known dyes, some (though comparatively few) may be applied to animal or vegetable stuffs without any other preparation than that of cleansing the stuff, and then immersing them in a decoction or infusion of the dye, which then becomes so permanently combined with the fibre as to resist the effect of washing and the bleaching power of the sun and air. But the greater number of dyes have such feeble affinity for fibre that no permanent combination can be effected between them in their simple state; to effect the combination, recourse is had to various substances having a strong affinity both for the fibre and the colouring matter; and the cloth being previously steeped in a solution of some of these substances, and afterwards immersed in the dye, an intimate union of the cloth and the colour-

ing mattter is effected. The substances which serve to fix the colouring matter in the cloth are termed mordants; and in the management and selection of them is the chief art of the dyer, as their effects are not limited to the fixing of the colour, but they, in most cases, produce some alteration in the natural hue,—a circumstance which the dyer avails himself of in numerous cases, to vary and improve the colour obtained from simple dye stuffs: thus aluminous mordant changes the dull red of madder to a bright crimson; and the solutions of tin not only fix cochineal in wool, but change it from crimson to bright scarlet; but if the oxide of iron be substituted for the tin as a mordant, the colour becomes changed to a black. In dying, then, it is necessary not only to procure a mordant for the colouring matter and the cloth, and a colouring matter which passes the desired colour in perfection, but to procure a mordant and colouring matter, which, when combined, shall produce the colour sought. It is also evident that a great variety of colours may be produced from a single dye stuff, provided the mordants can be sufficiently varied. Mordants are generally composed of earths or metallic oxides, tannin, and oil. Of earthy mordants, the most important and generally used is alumine, either in the state of common alum, in which it is combined with sulphuric acid, or in that of acetate of alumina, which answers much better than alum, as the cloth is more easily saturated with alumine, and takes, in consequence, a richer and more permanent colour. Almost all the metallic oxides have an affinity for cloth, but only two of them are extensively used as mordants, viz. the oxides of tin and of iron. The oxide of tin was first introduced in dying by Kuster, a German chemist, who brought the secret to London in 1543. It is generally employed in the state of nitro-muriate, muriate, or acetate of tin. Iron is generally employed in the state of the sulphate or the acetate; the first being chiefly used for wool, and the latter for cotton. Tannin has a very strong affinity for cloth, and for several colouring matters. It is principally obtained from nut galls, or sumach, which contain it in great quantities. Tannin is also often employed along with other mordants to produce a compound mordant. Oil is also used for the same purpose in dying cotton and linen. We now proceed to a consideration of the dyes, and commence by observing that innumerable as are the different colours and shades of colours communicated, they all originate from four or five primary dyes, modified according to the colour intended to be produced. These primary or simple dyes are as follow:—blue, yellow, red, black, and fawn, or brown colour.

Of Blue.—The only two substances used for dying blue are woad and indigo. Indigo has a very strong affinity for wool, silk, cotton, and linen, all of which may therefore be dyed with it without the assistance of any mordant. But indigo is soluble only in sulphuric acid; it is therefore necessary either to employ the sulphate of indigo, or to render it soluble in water, by depriving it of its oxygen. The first process is frequently employed for dying wool or silk; but for linen or cotton, the latter is generally resorted to. When the sulphate is employed, one part of indigo is to be dissolved in four parts of concentrated sulphuric acid, and one part of dry carbonate of potash added to the solution, which is then to be diluted with eight times its weight of water. The cloth must be boiled for an hour in a solution of five parts of alum and three of tartar, after which it must be removed to a bath containing a greater or smaller proportion of the sulphate of indigo, according to the shade which the cloth is to receive; and in this bath it must be boiled until it acquire the desired colour. The alum and tartar are not intended to act as mordants, but to facilitate the decomposition of the sulphate of indigo. The alkali added to the sulphate answers the same purpose. But the most common method of employing indigo is to deprive it of the oxygen to which it owes its blue colour, and thus reduce it to the state of green pollen, and then to dissolve it in water by means of alkalies or alkaline earths, which act very readily upon it in that state. It is deprived of oxygen either by admixture with other substances possessing a greater affinity for oxygen, as the green oxide of iron, or various metallic sulphurets; or it may be mixed in water with certain vegetable substances which readily undergo fermentation: the ferments most commonly employed

are woad and bran. During this fermentation, the indigo is deprived of its oxygen, and is then dissolved by means of quicklime or alkali added to the solution. The first of these methods is usually followed in dying cotton or linen; the second, in dying wool and silk.

Of Yellow.—This colour is most commonly obtained from weld, fustic, or quercitron bark. The cloth requires to be prepared before dying, by combining it with some mordant; that most commonly employed for this purpose is alumina.

Of Red.—The materials employed for this colour are lac or kermes, cochineal, archil, madder, carthamus, and Brazil wood; and the ordinary mordants are alumina, and the oxides of tin; various shades are produced by intermixture of the dying materials above named, or by first dying the stuff with one or more of them, and subsequently passing it through a yellow bath.

Of Black.—The substances employed to give a black colour are red oxide of iron and tannin. These two substances have a strong affinity to each other, and, when combined, assume a deep black colour, not liable to be decomposed by light. Logwood is usually employed as an auxiliary, because it communicates lustre, and adds considerably to the fulness of the black. Cloth, before it receives a black colour, is usually dyed blue, which renders the colour much fuller than it would otherwise be; for inferior cloth, a brown colour is sometimes given by means of walnut peel.

Of Brown, or Fawn Colour.—Various plentiful and cheap substances are employed to give a brown or fawn coloured ground, as birch, sumach, alder bark, but more especially decoction of walnut peels, or walnut bark or root. The shades produced by the bark or rind of the walnut tree are particularly fine, the colours solid, and it renders the wool, when dyed in it, flexible and soft. From the above colours variously combined are derived the endless gradations of tint imparted to the various fabrics of silk, wool, cotton, and linen. Of these compound colours we shall notice a few of the principal.

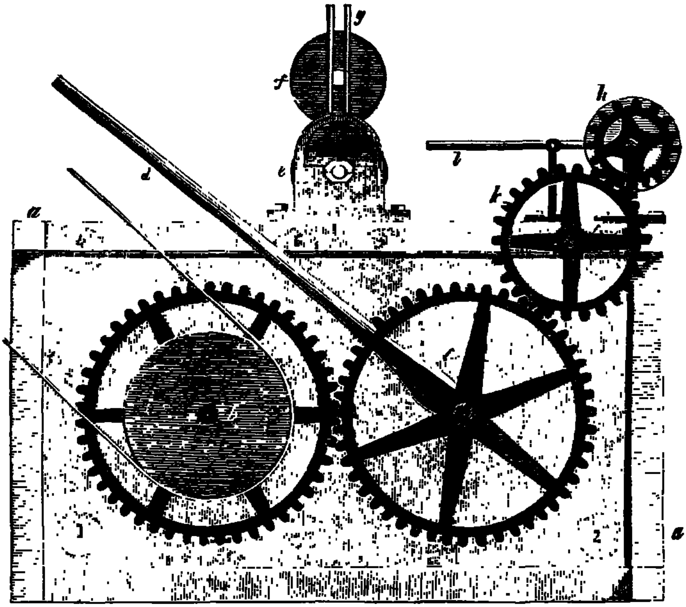
Of Green.—This is a mixture of blue and yellow, the shade varying according to the prevalence of either ingredient. The cloth is generally first dyed blue, and then immersed in a yellow bath; but when sulphate of indigo is employed, it is usual to mix the ingredients together, and dye the cloth at once.

Of Violet, Purple, and Lilac.—These are all mixtures of blue and red, and depend upon the different shade produced by the proportion of one colour to the other. Wool, cotton, and linen, are first dyed blue; the two last are then galled, and soaked in a decoction of logwood, or of green sulphate of iron; they are then dyed scarlet in the usual manner: by means, however, of cochineal, mixed with sulphate of indigo, the process may be performed at once. Silk is first dyed crimson with cochineal, and then dipped in the indigo vat.

Of Orange.—This is a mixture of yellow and red. A remarkable difference exists in the affinity of various substances for colouring matter, animal substances generally taking the dye much more readily than those of vegetable composition—thus wool and silk are more easily dyed than cotton and linen; the latter article, indeed, has so slight an affinity for the dye that it is extremely difficult to impart to it a bright and permanent colour. The processes and manipulations in dying are few and simple, and require principally a good eye to judge accurately of the gradations of the tints, and care and attention in preparing the ingredients, and in maintaining the baths at a proper temperature.

Mr. J. Hall, of Ordsall, near Manchester, has recently obtained a patent for an apparatus, shown in the engraving on the following page, the object of which is to cause the goods to be exposed to the action of the liquor in the dye vat in a more equal manner than is done in the ordinary method. In the dye vat *a* are placed six small rollers, 1 to 6, one at each corner, and two near the middle, on the same line with 1 and 4. At about half the depth of the vat are placed two large rollers *b* and *c*, about one foot asunder; one end of each of the axes of these rollers comes through a stuffing-box, and on the axis of *b* is placed a cog-wheel, which is connected with the axis by a pin passing through it that can be withdrawn at pleasure; on the axis of *c* is a similar wheel gearing into *b*, and may be thrown out of gear when required by

the lever *d*. On the top of the vat is the roller *e*, whose axis turns in bearings fixed in each side of the vats; and upon this roller another roller *f* rests, which can only move in a vertical direction, its axis being square, and confined by guides *g*. At one end of the vat is a roller *h*, supported in two upright forks, and having a small wheel on its axis; another wheel *k* on a short axis is placed between the last mentioned wheel and the wheel and the axis of *c*, and gears into each. The roller *h* may be lifted out of the forks by the lever *l*. To the roller *c* is fastened a piece of cloth of the width of the goods to be dyed; this cloth passes over the rollers 6 and 1, under 2 and 3, and over 4: a similar



piece of cloth is wound round the roller *b*, the end of which is brought up and hung over the roller 5. The cloth or web to be dyed is attached by a long skewer to the cloth of *c*, hanging over the roller 4: the wheel *b* being now unpinned, and set in motion by a band wheel, or other means, the web is wound upon *c*, passing under the roller, as before described, until the outer end arrives at the roller 4, when it is attached to the cloth of *b* by a skewer, and the wheel turned until the cloth on *b* is unwound. The wheel on *c* is next thrown out of gear, and that on the axis of *b* is pinned to its axis, when the wheel being again set in motion, the cloth is unwound from *c* and wound upon *b*; and it is thus wound alternately upon each of the rollers *b* and *c*, until it is deemed sufficiently dyed. It must then be wound upon the roller *b*, and the cloth, being detached from the web *c*, is passed between the rollers *e* and *f*, and made fast to the roller *h*. The wheel on *b* is then unpinned, and being set in motion, turns *h* by means of the wheel on *c*, and the small wheel *k*; the piece is thus wound upon the roller *h*, and deprived of a great portion of moisture by the pressure of the rollers *e f*. When the end appears above the roller 5, the skewer attaching it to the cloth of *b* is withdrawn, and the roller *h* is lifted out of the forks by the lever *l*, and replaced by a similar one.

DYNAMICS treats of the nature and laws of motion. In this sense it is used in opposition to STATICS. A single force, always producing motion, must be considered under the head of Dynamics; but two or more forces, accordingly

as they result in producing motion or not, constitute cases in STATICS or DYNAMICS. These two terms are frequently used to designate the two great divisions of mechanics—Statics, including all cases where equilibrium is produced, and Dynamics, those in which motion results. The term dynamics is, however, not confined exclusively to the motions of solid bodies. When applied to describe the laws of motion in fluids, it is termed hydrodynamics, and electro-dynamics when used to comprehend the phenomena of electricity in motion. See FORCES, MOTION, &c.

DYNAMOMETER. An instrument employed to measure the comparative

Fig. 2.

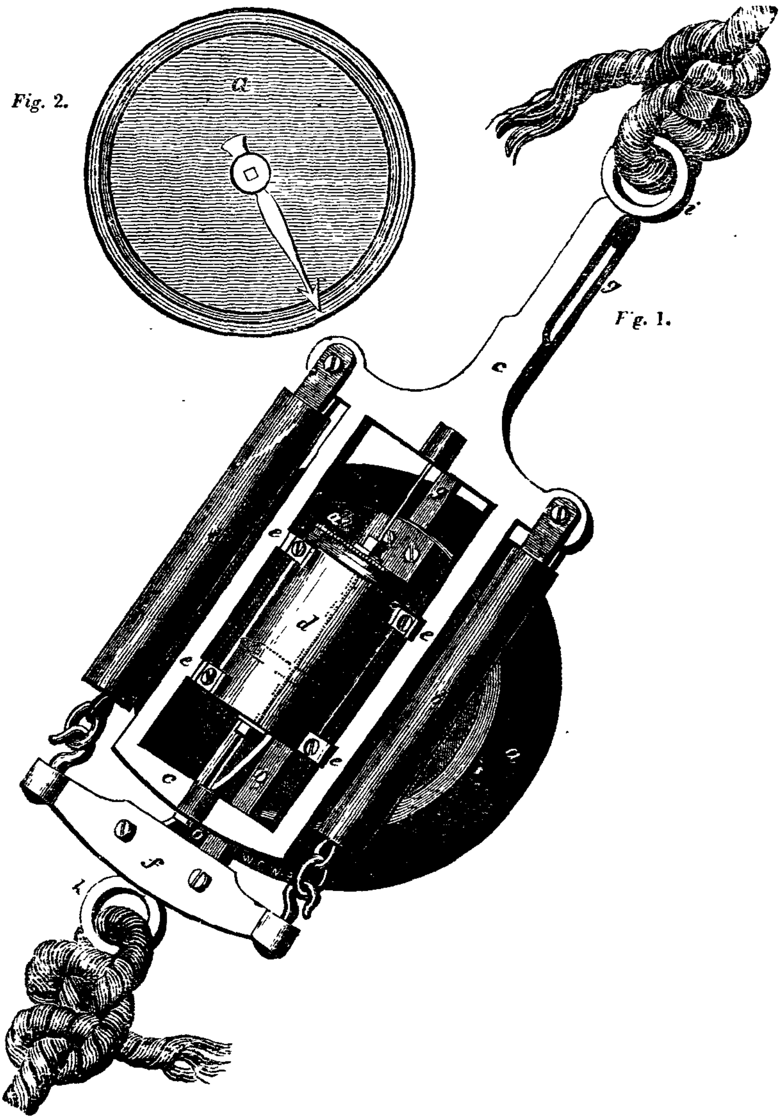


Fig. 1.

strengths of men and cattle, and to ascertain the force required in drawing

carriages upon land, and vessels upon canals. These effects are usually estimated by the compression or distension of a strong spring, or by a steelyard upon the principle of a bent lever balance; but in both these constructions the instrument is subject to great vibration, owing to inequalities in the resistance and in the moving force, which render the indications very uncertain. This objection to spring dynamometers has been obviated by Mr. H. R. Palmer, as follows:—a piston, fitting loosely in a cylinder filled with oil, so as to allow the oil to escape slowly past its sides as it moves up and down, is connected with the springs by means of a fine steel wire passing through stuffing boxes at each end of the cylinder; the friction, therefore, is so extremely slight as not to be worth taking into account in any experiments, whilst it prevents that vibratory motion of the index, from jerks, and allows the resistance to be ascertained with the greatest accuracy. The preceding engraving is a representation of the instrument. *a a* represents the back of the dial plate of any ordinary spring weighing machine, the front of which is shown separate in *Fig.* 2 (but without the graduated scale, as being unnecessary); *b b* are two spiral springs enclosed in cylindrical cases, (similar to the well-known domestic article called pocket steelyards,) the upper ends of which are fixed to a sliding frame *c c*, and at their lower ends they are hooked to a cross bar *f*, which bar is made fast to a piece of metal *o* at the back of *a a; d* is the cylinder of oil, which is firmly fixed at the back of *a a;* to this cylinder is fixed four pieces of metal *e e e e*, having angular grooves, in which the frame *c c* slides when the springs are acted upon. The piston in the cylinder is shown by dots, the rod to which (a fine steel wire) passes through stuffing boxes at each end of the cylinder, and each end of the rod is then made fast to the frame *c c*. Now the bar *g*, which proceeds from the circular box *a a*, and acts upon the spring, is connected at the swivel ring *i* with the upper end of the frame *c c*, as one solid piece; therefore when the ring *k* is made fast to a carriage, and power applied to the rope at *i*, the bar *g* is drawn out of *a*, while the frame *c c* acts simultaneously upon the steelyard springs *c c*, which move along with them the piston in the fixed cylinder *d;* the oil therein being incompressible, is compelled to pass from one side of the piston to the other, through the extremely narrow interstice between the periphery and the cylinder.

In the dynamometer invented by Mr. Milne, of Edinburgh, an iron plunger is by the force exerted in traction caused to descend in an open vessel containing mercury, by which means the latter rises to a height indicated by a glass tube open at top, and connected to the mercurial vessel at bottom by a neck, the bore of which is contracted to diminish the vibrations of the mercurial column; half the height in inches of the mercury in the tube multiplied by the area of the base of the plunger in inches will be the amount of the force of traction in pounds.

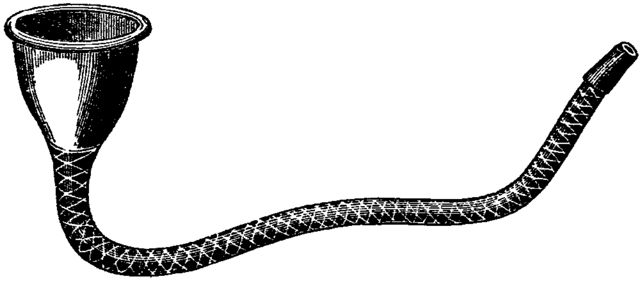
E.

EARTHS. A name commonly assigned to a class of solid substances composing, in various states of combination, the crust of the globe; the general qualities of which are, that they are incombustible, not convertible into metals by the ordinary methods of reduction, and their specific gravity not exceeding five times that of water. The number of these substances is ten; viz. barytes, strontites, lime, magnesia, alumina, or clay, silica, glucina, zerconia, yttria, and thorina. But although these substances are generally termed earths, the experiments of Sir H. Davy have shown that a portion of them, viz., barytes, strontites, and lime, as well as the alkalies, potash and soda, are, in reality, combinations of metallic bases with oxygen and lead, and determine, by most probable analogies, that the whole of them belong to the metallic class.

EARTHENWARE. Articles made of baked or vitrified earth. See Pottery.

EAR TRUMPET. A contrivance for the benefit of deaf persons; as usually constructed, it resembles in shape a marine speaking trumpet, but smaller, seldom exceeding six or eight inches in length. The party using the

trumpet inserts the small end within his ear, and the speaker applies his mouth to the wide end. Dr. Morrison, of Aberdeen, however, contends that this construction is erroneous, and that the end which is applied to the ear should be large enough to include the whole ear, instead of being inserted within it. The Doctor states, that having laboured under a deafness for a number of years, he applied in every quarter for the most improved ear trumpet; but from none of them could he derive the most trivial benefit. He at length ordered one to be made of the finest block tin, constructed as above recommended, and found it to answer beyond his most sanguine hopes. The annexed cut is a representation of a flexible ear trumpet, invented by Mr. T. Hancock, of Fulham. It is made of Indian rubber, covered with a net-work of gold or



silver wire, and, from its flexibility, is rendered more convenient for portability and for ready application in any situation that may be required. Mr. Hancock has successfully applied tubes of this description as speaking pipes, to communicate verbally with the various parts of an extensive manufactory.

EASEL. A frame used by painters for supporting their pictures while in progress, and admitting of being adjusted to any convenient angle by means of a movable prop at the back.

EAU-DE-LUCE. A volatile preparation, which is thus made:—12 grains of white soap are dissolved in 4 ounces of spirit of wine; this solution being strained, a drachm of rectified oil of amber is added, and the whole filtered. Afterwards, some strong volatile spirit of sal ammonia is to be mixed with the solution.

EAU-DE-COLOGNE. A celebrated odoriferous liqueur: the following is the true mode of preparing it. Take of the essence of bergamot, lemon peel, lavender, and orange flower, of each 1 ounce; essence of cinnamon, half an ounce; spirit of rosemary, and of the spirituous water of melisse, each 15 ounces; strong alcohol, 7½ pints. Mix the whole together, and let the mixture stand for the space of a fortnight; after which introduce it into a glass retort, the body of which is immersed in boiling water, contained in a vessel placed over a lamp, while the beak is introduced into a large glass reservoir well luted. By keeping the water to the boiling point, the mixture in the retort will distill over into the reservoir, which should be covered with wet cloths. In this manner will be obtained pure eau-de-Cologne.

EAVES. The edge or margin of the roof of a house, which projects beyond the walls to throw off the water therefrom.

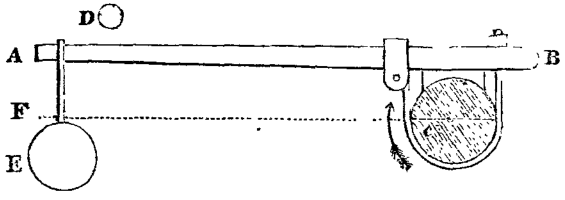
EBONY. An exceedingly hard and heavy wood, susceptible of a fine polish. There are many kinds of ebony; the most usual are the black, red, and green, all of them the product of the island of Madagascar. The black ebony is preferred to that of any other colour, but it is not so much in request as formerly, since the discovery of so many ways of giving other hard woods a black colour. This may be done by boiling smooth, clean box wood in oil till it becomes perfectly black; or by washing pear wood with aquafortis, and drying it in a

shady place in the open air; after which common writing ink should be repeatedly passed over it, and the wood dried in a similar manner till it acquire a deep black colour. It may then be polished with wax and a woollen cloth, which will give it a fine lustre. An excellent black is also produced by first applying a solution of copper and aquafortis, and afterwards brushing the wood over with a decoction of logwood.

ECCENTRIC, in Geometry, denotes two circles or spheres, one of which is contained within the other, but the centres of the two do not coincide. In mechanics, the name is given to a contrivance frequently substituted for a crank, for obtaining a reciprocating motion from a circular. It consists of a circular disc placed eccentrically upon a shaft, and revolving within a hoop formed at one end of the connecting rod. The valves of most steam engines which work with a fly-wheel are moved by an eccentric.

EDGE TOOLS is a general name applied to the coarser kinds of cutting instruments, such as chisels, axes, adzes, gouges, augers, saws, &c.

EFFECT (Useful), in Mechanics; the measure of the real power of any machine, after deducting that portion which is lost or expended in overcoming the inertia and friction of the moving parts, and in giving them the required velocity, and every other source of loss. The greatest useful effect which a horse can produce, was estimated by Bolton and Watt at 33,000 lbs. raised one foot high per minute; and upon the introduction of the steam engine to perform the labour which was before performed by horses, their power was expressed by that of the number of horses which they were equal to; and from the convenience of this mode of expression, it has since been generally adopted to express the power of all kinds of machinery. It is at all times desirable to know the real effective power of any machine: when water is to be raised, the effect is readily computed, but in most other species of work it is difficult to estimate the resistance, and consequently whether the engine be really equal to its nominal power; in this case, Mr. Tredgold observes, the most convenient and simple mode of measuring the effect is by friction. If the rim of a brake wheel of known diameter upon an engine shaft be pressed with a force producing a known degree of friction, which is exactly equal to the effect of the engine at its working speed, then it is clear that if the friction this pressure produces be ascertained, the power of the engine will be equal to the friction multiplied by the velocity of the rubbing surface. To apply this, let A B be a lever with a friction strap, that may be tightened upon the cylindrical surface of the shaft or wheel C, and let it be tightened by the screw at B (the lever being stopped by the stop at D), till the friction be equal to the power of the engine when all other work is thrown off; then while the engine is still in motion, add such a weight at E as retains the lever in a horizontal position.



To calculate the power, multiply together the length of the lever F C in feet, the weight E in lbs. the number of revolutions of C per minute, and the number 6.2832; the result will be the number of pounds raised one foot per minute, and divided by 33,000 it is the horses' power. Thus if a shaft make 20 revolutions per minute, and the length E C of the lever be 10 feet, and if it be found that a weight of 240 lbs. is sufficient to retain the lever in a horizontal position, then 6.2832 × 10 × 240 × 25=376992 lbs. raised one foot high, or nearly eleven and a half horses' power.

EFFERVESCENCE. The commotion produced in fluids by some part of the mass taking suddenly the elastic form, and escaping rapidly in numerous bubbles.

EFFLORESCENCE. The effect which takes place when bodies spontaneously become converted into a dry powder. It is almost always occasioned by the loss of the water of crystallization in saline bodies.

EGGS. The envelope which contains the fœtus of various animals, and which, being voided by the parent, is subsequently matured by incubation. This may also be effected by means of prolonged artificial heat; and in Egypt the art of hatching chickens by means of ovens has long been practised, but it is there only known to the inhabitants of a single village, named Berme, and to those that live at a small distance from it. Towards the beginning of autumn they scatter themselves all over the country, where each person among them is ready to undertake the management of an oven, each of which is of a different size, but in general they are capable of containing from forty to fourscore thousand eggs. The number of these ovens placed up and down the country is about 386, and they usually keep them working for about six months; as, therefore, each brood takes up in an oven, as under a hen, only twenty-one days, it is easy in every one of them to hatch eight different broods of chickens. Every Bermean is under the obligation of delivering to the person who entrusts him with an oven, only two-thirds of as many chickens as there have been eggs put under his care; and he is a gainer by this bargain, as more than two-thirds of the eggs usually produce chickens. In order to make a calculation of the number of chickens yearly so hatched in Egypt, it has been supposed that only two-thirds of the eggs are hatched, and that each brood consists of at least 30,000 chickens; and thus it would appear that the ovens of Egypt give life yearly to at least 92,640,000 of these animals. As it is of great importance in a zoological, and, to a certain extent, even in an economical point of view, to be able to transport eggs fresh from one country to another, it has been proposed, as the best method of effecting this, to varnish them with gum arabic, and then imbed them in pounded charcoal, which being a non-conductor of heat, a uniform temperature will be preserved.

ELAINE. The oily principle of solid fats, the remaining or solid portion being named stearine,—names assigned to these substances by the discoverer, Mr. Chevreul. If tallow be squeezed between the folds of porous paper, the elaine soaks into it, whilst the stearine remains. The paper being then soaked in water and pressed, yields up its oily impregnation. Elaine has very much the appearance and properties of vegetable oil, and is liquid at the temperature of 60°. Cocoa nut oil, which in England usually is concrete, or at most semi-fluid, has of late years been resolved into the above-named constituents by mechanical pressure, and the solid part manufactured into candles, whilst the liquid forms a valuable oil for lamps. See FAT.

ELASTICITY. A property of bodies to resume their form upon the removal of any force by which they may have been deflected from it. In this respect all bodies which come within our knowledge are comprehended under one of these three distinctions. If two bodies, when pressed together, suffer an alteration in their form, and if afterwards, on removing that pressure, they recover their original figures, they are called *elastic;* if, when pressed, their forms are not in the least altered, they are called *hard;* and if, when pressed as above, they alter their forms, and retain the same after the pressure is discontinued, they are called *soft;* and both these last kinds of bodies are termed non-elastics. It is doubtful, however, whether any bodies are either *perfectly* hard, or soft, or elastic, —the air not being perfectly elastic, and water (which was for a long time held to be perfectly incompressible and non-elastic,) being in the opinion of many persons shown to be compressible, by the experiments of Canton and of Perkins.

ELECTRICITY. The name assigned to a certain mysterious natural principle or element, with the nature of which we are totally unacquainted, as it can only be inferred from its effects, in which respect it resembles the principles of light, heat, and magnetism. For a brief outline of the science of electricity, see CHEMISTRY.

ELEMENTS. The name assigned by the ancients to those simple substances of which, by combination, all bodies were supposed to be formed. These principles were supposed to be four in number, viz. fire, water, earth, and air; but the researches of modern chemistry have completely overturned this classification, showing that each of these supposed elements is in reality composed of two or more substances, and extending the number of simple substances to nearly fifty; at the same time it is to be observed that these substances are not pronounced to be absolutely simple, but are merely so in respect to the present state of the art of analyzing bodies. For a list of the simple or undecompound substances, see CHEMISTRY.

ELEVATION, in the art of design, an orthographic projection of the vertical figure of any building or piece of machinery, there being no vanishing points, as in a perspective representation, but the eye being supposed to occupy the whole space of the picture, or every part of the object being deemed perpendicular to the eye.

ELIQUATION. An operation by which one substance is separated from another that is less fusible. It consists in the application of a degree of heat sufficient to fuse the former, but not the latter.

ELIXIR. A compound tincture extracted from many ingredients, whereas, a simple tincture is extracted from only one ingredient.

ELLIPSIS, in Geometry, a curve line returning into itself, and produced from the section of a cone by a plane cutting both its sides, but oblique to the axis of the cone.

EMBOLUS. Any thing inserted and acting in another, as the sucker of a pump, the piston of a steam engine, &c.

EMBOSSING. The forming of ornaments in relief upon any substances, whether by sculpture, casting, stamping, or any other means. One pleasing species of embossing is that by which the leather covers of books are now so richly ornamented; this is effected by means of a metal plate on which the pattern is engraved, and which, being heated, gives the impression to the leather by the action of a powerful fly-press. The following method of embossing on wood, invented by Mr. Straker, is extracted from the *Transactions of the Society of Arts*; it may be used either by itself, or in aid of carving, and depends on the fact, that, if a depression be made by a blunt instrument on the surface of wood, such depressed part will again rise to its original level by subsequent immersion in water. The wood to be ornamented having first been worked out to its proper shape, is in a state to receive the drawing of the pattern; this being put in, a blunt steel tool, or burnisher, or die, is to be applied successively to all those parts of the pattern intended to be in relief, and at the same time is to be driven very cautiously without breaking the grains of the wood, till the depth of the depression is equal to the subsequent prominence of the figures. The ground is then to be reduced by planing or filing to the level of the depressed part; after which the piece of wood being placed in water, either hot or cold, the parts previously depressed will rise to their former height, and will thus form an embossed pattern, which may be finished by the usual operation of carving.

EMBROIDERY. The enriching of cloth, stuff, or muslin, by figures worked thereon with a needle, with thread of gold, silver, silk, or cotton. The embroidery of stuffs is performed in a kind of loom; that of muslin by stretching it on a pattern already designed, and the thinner the muslin the better it is adapted to the purpose.

EMERALD. A well-known gem, of a pure green colour, somewhat harder than quartz, though softer than most of the precious stones. Owing to the beauty of its colour, and the fine contrast it makes with brilliants, it is valued next to the ruby. The oriental emerald is considered to be a variety of ruby of a green colour.

EMERY. A very hard mineral, of a dark grey colour. The best is obtained from the island of Naxos, whence it is imported into this country; it is found in irregular masses, mixed with other minerals. It is so hard as to scratch topaz. Its constituents are 86 alumina, 3 silicia, 4 iron, and 7 loss. Its

specific gravity is 4.0. Emery is also obtained from some of the iron mines in this country. The extreme hardness of this substance has caused it to be employed in various arts. Lapidaries employ it in cutting and polishing of precious stones; opticians, in grinding glass preparatory to polishing. It is very extensively used by the manufacturers of iron and steel wares; is a common household material for brightening iron; and is applicable as a grinding, scouring, and polishing powder, in a great variety of operations. For all these purposes it is first pulverized in large iron mortars, and the powder, which is very sharp, is frequently washed to free it from foreign matters; it is then dried, and afterwards sifted into six or more different degrees of fineness, for the various purposes before mentioned.

EMPYREUMA. A term implying a peculiar odour derived from the overheating of matters under the process of distillation, or when vegetable or animal matter becomes burned in other processes in close vessels. It is said that this peculiar odour is produced from no substance that does not contain oil; hence, if no empyreuma is perceived in burning any substance in a close vessel, we may be assured that it contains no oil.

ENAMEL. A shining vitrified substance, employed as an indestructible coating to pictures, and various articles of taste and utility. The basis of all kinds of enamel is a perfectly transparent and fusible glass, which is subsequently rendered either semi-transparent or opaque by the admixture of metallic oxides. White enamels are composed by melting oxide of tin with the glass, and adding a small quantity of manganese to increase the brilliancy of the colour. The addition of the oxide of lead or antimony produces a yellow enamel. Reds are formed by an admixture of the oxides of gold and iron. Greens, violets, and blues, are procured from the oxides of copper, cobalt, and iron; and these, when intermixed in different proportions, afford a variety of intermediate colours. The proportion in which these ingredients are used, as well as the degree and continuance of the heat necessary to their perfection, constitute the secrets of the art. The best enamel was formerly imported from Venice; but during the restrictions on commerce imposed by the late war, the importation had almost wholly ceased. The high price of the article, therefore, induced British artisans to attempt its manufacture, and they succeeded in producing a hard enamel, superior to the best Venetian in whiteness, and much more valuable to the dial-plate makers. In 1817 Mr. Wynn communicated to the Society of Arts a series of receipts for the preparation of enamel colours, and for which a premium was awarded by the Society. The fluxes are those employed by Mr. Wynn."

		Parts.
No. 1.	Red lead	8
	Calcined borax	1½
	Flint powder	2
	Flint glass	6
No. 2.	Flint glass	10
	White arsenic	1
	Nitre	1
No. 3.	Red lead	1
	Flint glass	3
No. 4.	Red lead	9½
	Borax, not calcined	5½
	Flint glass	8
No. 5	Flint glass	6
	Flux, No. 2.	4
	Red lead	8

After the fluxes have been melted they should be poured on a wetted flag-stone, or into a large pan of clean water, then dried, and finely powdered in a biscuit-ware mortar for use.

To make *yellow* enamel: take red lead 8 parts, oxide of antimony 1, and white oxide of tin 1. Mix the ingredients well in a biscuit-ware mortar, and having put them on a piece of Dutch tile in the muffle, make it gradually red

hot, and suffer it to cool. Take of this mixture 1 part, of flux, No. 4, 1½, and grind them in water for use. By varying the proportions of red lead and antimony, different shades of colour may be obtained.

To make *orange* enamel: take red lead 12 parts, red sulphate of iron 1, oxide of antimony 4, and flint powder 3. After calcining these without melting, fuse 1 part of the compound with 2½ of flux.

To make *dark red* enamel: take sulphate of iron, calcined dark, 1 part, flux, No. 4, 6 parts, and of colcothar 1 part; of the two latter mixed, add 3 parts.

To make *light red* enamel: take red sulphate of iron 1 part, flux, No. 1, 3, and white lead 1½.

To make *brown* enamel: take maganese 2½ parts, red lead 8½, flint powder 4.

ENAMELLING. The art of covering plates of metal with enamel is of great antiquity; it was practised by the Egyptians, and by them probably transmitted to the Greeks and Romans. Several ancient specimens of curious workmanship prove its existence in Britain at a very early period. It was formerly employed chiefly for ornamental purposes, but since the invention of clocks and watches, its usefulness has been proportionably increased. For clock and watch dials there is probably no substance that could be substituted that can equal enamel in permanence and beauty. The art of dial-plate enamelling is divided into two branches, namely, hard enamelling, and soft or glass enamelling. In the first branch the Venetian enamels are chiefly employed; in the last the English or glass enamels. The practice of hard enamelling requires more skill, time, and labour, than the others, and is consequently the most esteemed. The metals to be enamelled on are usually gold, silver, or copper; but the process being similar, one description will suffice. The copper, which is the metal usually employed, being evenly flatted in long slips, and to a proper thickness, pieces are cut off for use according to the size wanted; they are then annealed in a clear fire in order to make them sufficiently pliable to take the required forms which are given to them by means of brass dies. A complete set of dies varies in size from about three-fourths of an inch, to two inches and a half, the gradations being very small. The copper is next placed on the die best adapted for the purpose, and the eye, or centre hole, is made with a small round-headed punch, and smoothed with a grained file; it is then again placed on the die, and pressed gradually open, till it nearly fills the hole with an oval burnisher; it is afterwards pressed tighter into the hole with a round broach, the burr being occasionally taken off by the file, and care employed to prevent the eye from cracking. The punch, burnisher, and round pin, are all of steel; the two latter taper in regular gradation towards the handles. When the eye is completed, the edge of the copper is cut round, so as to leave a small part projecting beyond the die, which is then turned up or burnished against the edge of the die, the copper being first laid smooth and flat by the burnisher. The copper is then gradually set up to the convexity or height required by rubbing it gently, yet firmly, with a bent or setting spatula, formed of a thin slip of steel about five inches long, properly fixed, after which the feet are soldered on. The inconveniences that attended the use of plain copper wire, soldered with spelter for the feet, are now entirely obviated by employing copper wire plated with silver. The feet must be cut by fixing an iron peg into the work-board; to the pieces of plated wire being held against it, it will be found to form a very good resistance against the action of the file. It should be observed, that if coppers are to be made for flat plates, the feet should be filed at right angles; but if the plates are convex, they should be filed at an angle as nearly as possible corresponding with the curve formed in the hollow part of the copper, because when the foot is placed on the copper it will be found to stand perpendicular to the base line or edge of the copper. In order to make the feet remain in their places, and facilitate the soldering, the end of each foot, before putting it on the copper, which is done by means of a pair of corn tongs or tweezers, is dipped into a slight wash of borax and water, through which it adheres with sufficient force to admit of its being exposed to the power of the blow-pipe. The lamp in common use contains from a pint to a quart of oil, and has a cylindrical spout projecting

about three inches, being an inch or more in diameter. This space is filled with cotton, which being lighted, a strong flame is produced. The copper is carefully placed upon a piece of solid charcoal, long enough to be held in the hand; and the flame being then propelled by the blow-pipe against the solder or silvered wire, as the case may be, the feet are firmly united to the copper. The whole is then thrown into the pickling-pan, in order to free it from the scale or oxidable covering acquired from the heat. The coppers being thus prepared, the next process is that of enamelling, properly so called. The operations of hard enamelling, and glass enamelling, are, to a certain extent, the same. When they are different, we shall describe the difference as we proceed. The enamel, as it comes from the makers, is generally in small cakes from four to five or six inches in diameter. It is first broken with a hammer, and then ground in a mortar, and moistened with water; after which, the coppers having been first cleansed by the pickle, and carefully brushed out with water, are spread, face downwards, over a soft cloth, or smooth napkin, and a thin layer of hard enamel, called in its ground state the *backing*, is spread over the under sides with the end of a quill, properly cut, or with a small bone spoon. The coppers are then slightly pressed on by another soft cloth or napkin, which, by imbibing some portion of the water, renders the enamel sufficiently dry to be smoothly and evenly spread with the rounded side of a steel spatula. The next operation is to spread a layer of glass enamel over the upper sides of the coppers, called the *first coats*. In doing this, the surface is first brushed slightly over with a small camel-hair brush, or a hare's foot, to remove any dirt or extraneous particles of enamel, as the mixture of any hard enamel with the glass would infallibly spoil the work. The glass is then spread upon the coppers in a layer, the thickness of which is commonly the same as the height of the edge and eye. The water is afterwards slightly absorbed with a clean napkin, smoothly folded, and the enamel spread by a thin flat spatula, till all unevenness is removed, and the surface lies regularly from edge to centre. The next department is *firing*, as it is technically called, which consists in melting it till it becomes one uniform mass on the surface of the copper. In doing this, the first coats are placed upon rings, which are generally made of a mixture of pipe-maker's clay and Stourbridge clay, rolled up into the form of cylinders, and turned in a lathe by means of a cylindrical piece of wood forced through the centre of the mass when wet. They are next put into a shallow tin vessel called a tin cover, which is either made square or round, according to the fancy of the artificer, and is commonly about three quarters of an inch in depth. All the moisture is then slowly evaporated from the enamel, by placing the cover upon a German stove, or in some other convenient situation near a fire, where the evaporation can be properly regulated. The firing is executed beneath a muffle, placed in a small furnace, ignited with coke and charcoal. The furnace being drawn up to a sufficient heat by means of a register, the first coats are taken separately from the tin covers and placed upon thin planches of clay, or iron chalked over, and gradually introduced beneath the muffle, where, in a very short time, the enamel melts or *runs*, and becoming properly consolidated, the first coat is complete. A second layer of ground enamel is then gently spread with a quill, and prepared for firing by the napkin and spatula as before; after which the second coats are placed upon the rings, and the moisture being evaporated in the tin cover, they are ready for a second fire. This requires an equally cautious management as the former one. The plates must not be over-fired, nor must the heat be suffered to melt the enamel too rapidly, but a kind of rotatory motion, called coddling, must be given to the work, by holding the loaded planch lightly with the tongs, and gently drawing the edge of it towards the mouth of the muffle, and then returning it to its former place, till the fusion be complete. The work is now in a fit state for polishing, technically called *using off*. This is performed by rubbing the surface of the plate on a grit stone with fine sand and water, until all the glazed appearance is completely obliterated, and one uniform and equally rough surface is produced. The intention of this part of the process is to remove the mottled appearance on the surface, and give a more equal convexity to the plate.

The foregoing is an outline of the process for glass enamel plates. The firing of the Venetian hard enamel is much the same; but the heat applied to melt it must not be so great, and the plate must be taken from the fire as soon as the enamel is found to form one tolerably compact body, as any longer continuance would have a tendency to spoil the intended shape of the plate, which is always considered a most essential quality in those of hard enamel. The heat for finishing may be rather more than that used in the first fires, as in that instance the intention was only to unite the particles of enamel into one solid mass: but the principal object in finishing being to raise the flux to the surface as much as possible, a greater heat may be used with advantage, but the plate must be taken from the furnace the instant that the surface appears bright and glossy. Where good Venetian enamel cannot be obtained, and mixtures of various kinds are resorted to, it frequently happens that the glass enamel plates crack when they are brought to the second fire. When this is the case, as soon as the crack is observed the plate must be withdrawn from the fire; and if it extends only from the centre hole to the edge, it will, in most cases, bear mending; but if it has happened in two or three places, it will be useless to make the attempt, as it will rarely succeed. If the dial plate was to continue in the fire after it is cracked a sufficient time, the enamel would close, and the plate become sound again; but as the copper on its surface is in a state of oxidation, the oxide of copper uniting with the enamel would rise to the upper surface of the plate, producing by its union a faint and sometimes a dark green line, which would evidently render the plate useless. The operator, therefore, must observe the time when the crack has opened to its greatest width, and before it unite or close at the bottom the plate must be withdrawn from the furnace and allowed to cool. The opening must then be filled with fine enamel, laid sufficiently high to allow for its running down in the fire; but to adjust the quantity so as to prevent the appearance of a seam across the plate will require much judgment; and, indeed, however well the operation may succeed, it will still remain visible.

The method of painting in enamel is performed on plates of gold, silver, and copper, enamelled with the white enamel; whereon they paint with colours which are melted in the fire, by which they acquire a brightness and lustre like that of glass. This painting is the most prized of all for its peculiar brightness and vivacity, which is very permanent, the force of its colours not being effaced or sullied with time as in other painting, and continuing always as fresh as when it came out of the workman's hands.

ENAMELLED CARDS is a name given to the cards on which a coating in imitation of real enamel is produced. We believe there are various processes at present employed for fabricating these elegant and fashionable articles; but the following account of Mr. Christ's process, which we derive from the specification of his patent, enrolled in August 1826, may be regarded as genuine and practical. One pound of parchment cuttings, a quarter of a pound of isinglass, and a quarter of a pound of gum arabic, are to be boiled in an open iron pot or other vessel, in twenty-four quarts of pure water, until the solution is reduced to twelve quarts, when it is to be taken off the fire and strained clear. The solution of this consistence is then to be divided into three equal parts of four quarts each; to the first of these portions is to be added six pounds of pure white lead, (previously ground fine in water,) which is called mixture No. 1; to the second portion, eight pounds of pure white lead, forming mixture No. 2; and to the third is to be added six pounds of pure white lead, making mixture No. 3. The sheets of paper are then to be stretched out upon flat boards and brushed over with a thin coat of No. 1 mixture, with a common painter's brush; the paper is then to be hung up to dry for twenty-four hours. After this, the paper is in a similar manner to receive a coat of No. 2 mixture, and to be hung up again to dry for twenty-four hours; the paper is then to be treated in the like manner with No. 3 mixture, and then dried again for twenty-four hours. It is next to be printed with the engraved plate, and the press-board used for the purpose is to be of smooth cast iron instead of wood. The printing being completed, the paper is to be hung up a fourth time for twenty-four hours to

dry; after this it undergoes the final operation of receiving its high gloss, which consists in laying the work with its face downwards on a highly-polished steel plate, and then passing both with great pressure between a pair of cylindrical rollers, and thus the beautifully polished surface of the steel is transferred to the composition on the paper, which closely resembles in appearance the finest white enamel. It is, however, to be regretted that this enamelled surface is not very durable, as it comes off readily after wetting it with the finger. To prevent this, a solution of some resinous substance should be added in the last operation.

ENCAUSTIC PAINTING. A method of painting, much in use among the ancients, in which wax was employed to give a gloss to the colours, and permanence to the work. From the meagre account given to us by Pliny of the method, it is evident he was not in the secret himself; all the information he affords amounts to this — that the colours made use of were fixed by fire, and that wax was employed to give them a gloss, and preserve them from being injured by the air. This ancient art, after having been long lost, was restored by Count Caylus, a member of the Academy of Inscriptions at Paris; and the method of painting in wax was announced to the Academy of Painting and Belles-Lettres in the year 1753, through M. Bacheleir, the author of a treatise *de l'Histoire et du Secret de la Peinture en Cire*, who had actually painted a picture in wax in 1749, and he was the first who communicated to the public the method of performing the operation of inustion, which is the principal characteristic of the encausting painting. The cloth or wood designed for the basis of the picture is waxed over, by only rubbing it simply with a piece of bees' wax, the wood or cloth stretched on a frame being held horizontally over, or perpendicularly before, a fire, at such a distance that the wax might gradually melt, whilst it is rubbed on, diffuse itself, penetrate the body, and fill the interstices of the texture of the cloth, which, when cold, is fit to paint upon. But as water colours, or those that are mixed up with common water, will not adhere to the wax, the whole picture is first to be rubbed over with Spanish chalk or white, and then the colours are applied to it; when the picture is dry it is put near the fire, whereby the wax melts, and absorbs all the colours. Several improvements in the art of encausting painting were proposed by Mr. J. H. Muntz, in a treatise by him on this subject. When the painting is in cloth he directs it to be prepared by stretching it on a frame, and rubbing one side several times over with a piece of bees' wax, or virgin wax, till it is covered with a coat of considerable thickness. In fine linen this is the only operation necessary previous to painting, but coarse cloth must be gently rubbed on the unwaxed side with a pumice stone, to take off all those knots which would prevent the free and accurate working of the pencil. Then the subject is to be painted on the unwaxed side with colours prepared and tempered with water; and when the picture is finished, it must be brought near the fire, that the wax may melt and fix the colours. This method, however, can only be applied to cloth, paper, or other substances through which the wax can pass; but in wood, stone, metals, or plaster, the method previously described may be observed. In the year 1787, Miss Greenland, an amateur of painting, communicated to the Society of Arts the knowledge of this art which she had acquired during her residence at Florence, and at the same time made a present to the Society of a picture executed by herself in this manner, and for which the Society awarded her their honorary reward of a gold pallet. The following are her instructions. "Take an ounce of white wax, and the same weight of gum mastich, powdered. Put the wax in a glazed earthen vessel over a very slow fire, and when it is quite dissolved throw in the mastich, a little at a time, stirring the wax continually until the whole quantity of gum is perfectly melted and incorporated; then throw the paste into cold water, and when it is hard take it out of the water, wipe it dry, and beat it in one of Mr. Wedgwood's mortars, observing to pound it first in a linen cloth, to absorb some drops of water that will remain in the paste, and prevent the possibility of reducing it to a powder, which must be so fine as to pass through a thick gauze. It should be pounded in a cold place, and but a little while at a time, as after long beating

the friction will in a degree soften the wax and the gum, and instead of their becoming a powder, they will return to a paste. Make strong gum arabic water, and when you paint, take a little of the powder, some colour, and mix them together with the gum water. Light colours require but a small quantity of the powder, but more of it must be put in proportion to the body and darkness of the colours; and to black there must be almost as much of the powder as colour. Having mixed the colours, and no more than can be used before they get dry, paint with fair water, as is practised in painting with water colours, a ground on the wood being first painted of some proper colour, prepared in the same manner as is described for the picture; walnut-tree and oak are the sorts of wood commonly made use of in Italy for this purpose. The painting should be very highly finished, otherwise, when varnished, the tints will not appear united. When the painting is quite dry, with rather a hard brush, passing it one way, varnish it with white wax, which should be put into an earthen vessel and kept melted over a very slow fire till the picture is varnished, taking great care that the wax does not boil. Afterwards hold the picture before the fire, near enough to melt the wax, but not to make it run; and when the varnish is entirely cold and hard, rub it gently with a linen cloth. Should the varnish blister, warm the picture again very slowly, and the bubbles will subside. When the picture is dirty, it need only be washed with cold water." Almost all the colours that are used in oil painting may be employed in the encaustic method, and many which cannot be admitted in oil painting, as red lead, red or piment, crystals of verdigris, and red precipitate of mercury, may be used here. The crayons used in encaustic painting are the same with those used in the common way of crayon painting, excepting those that are in their composition too tenacious, and the method of using them is the same in both cases. The encaustic painting has many peculiar advantages; though the colours have not the natural varnish or shining they acquire with oil, they have all the strength of painting in oil, and all the airiness of water colours, without partaking of the apparent character or defects of either; they may be looked at in any light, and in any situation, without any false glare; the colours are firm, and will bear washing; and a picture after having been smoked and then exposed to the dew, becomes as clean as if it had just been painted. In retouching the new colours unite with the old ones.

ENCHASING, or Chasing. The art of enriching and beautifying gold, silver, and other metal work, by some design or figures represented thereon in low relievo. It is practised only on hollow thin works, as watch cases, &c., and is performed by punching or driving out the metal from the under side, so as to stand out prominent from the plane or surface of the metal. In order to effect this, a number of steel blocks or puncheons are provided of different sizes, and the design being drawn upon the surface of the metal, the workman applies the inside upon the heads or tops of these blocks directly under the lines or parts of the figures; then with a fine hammer striking on the metal sustained by the block, the metal yields and the block makes an indenture or cavity on the inside, corresponding to which there is a prominence on the outside, which is to stand for that part of the figure, and by successive applications of the hammer to the various parts of the design, the whole figure is brought out with a precision and effect which it seems almost impossible to produce by such simple means.

ENGINE, among practical men, is a term used synonymously with machine; but some eminent writers on Mechanics affect to distinguish it as designating more complicated structures than ordinary machines, notwithstanding which discrimination, these same writers define a cannon, which consists essentially of only one piece or part, as an engine; and a jacquard loom, which essentially consists of several hundred parts, as a machine!

ENGRAVING. The art of producing figures or designs upon metals, stone, wood, and various other substances, by means of lines cut upon the surface. In this extensive sense of the term, the art is doubtless of very great antiquity, repeated mention being made in Scripture of seals, signets, and other works of the graver; but the word usually signifies the art of producing

designs as above for the purpose of being subsequently printed upon paper, which copies are also called engravings; and in this sense of the term the art does not appear to have been known or practised in Europe until the middle of the fifteenth century. In the present day it is held in very great esteem, and is very extensively practised. It may be divided into two branches, according to the substances upon which the design is engraved, which is generally either metal or wood, although glass and other substances have been occasionally employed. Of the metals, copper has, until within these few years, been almost exclusively chosen for engraving, on account of its ductility, evenness of texture, and the softness and delicacy of the tints which may be produced upon it; but latterly, steel plates have been very extensively employed for this purpose, and although the engravings thus produced are perhaps somewhat inferior in softness to those obtained from copper, a very high pitch of excellence has been attained, and in point of durability the copper-plates will bear no comparison with steel-plates. Engraving on copper is performed in various styles, the principal of which are, line engraving, mezzotinto, etching, and aquatinta.

Line Engraving is considered as the highest department of the art, and is always employed in the illustration of historical subjects. In this style of engraving the lines are all cut upon the copper by means of an instrument called a graver, the roughness being removed by a triangular steel instrument called a scraper. To trace the design upon the plate (which for every style of engraving should be of the best copper well planished and burnished), it is usual to heat the plate sufficiently to melt white wax, with which it must be covered equally with a thin film, and then suffered to cool; the drawing is copied in outline with a black lead pencil on paper, which is then laid with the pencilled side upon the wax, and the back rubbed gently with a burnisher, which will transfer the lead to the wax. The design is then traced with an etching needle through the wax on the copper, when on wiping it clean it will exhibit all the outlines ready for the engraver.

Mezzotinto Engraving differs entirely from the manner above described, and is chiefly employed for portraits and imitations of Indian ink drawings. The mode of proceeding is as follows:—the plate is prepared by scratching it equally in every direction with a tool called a grounding tool, so as to remove entirely the polish from the surface, which is thus converted into a chaos of intersections, which, if covered with ink and printed, would present a perfectly black impression upon the paper. To transfer the design to be scraped, it is usual to rub the rough side of the plate with a rag dipped into the scrapings of black chalk, or to smoke it with a burning wax taper, as in the process of etching. The back of the design is then covered with a mixture of powdered red chalk and flake white, and laid on the plate, and the outline of the design being lightly traced with a blunt point, the red particles at the back are thus transferred to the black ground of the plate in the form of a corresponding outline; the process must then be carried on with a scraper, by restoring the plate in the perfectly light parts of the intended print to a smooth surface, from which the gradations are preserved by scraping off more or less of the rough ground, but the burnisher is necessary to polish the extreme edges of drapery, &c., when the free touch of the brush in painting represents a brilliant spot of light. The deepest shades are sometimes etched and corroded by aquafortis, and so blended with the mezzotinto ground added afterwards, that there is nothing offensive to the eye in the combination. Many proofs are required to ascertain whether the scraping approaches the desired effect, which is done by touching the deficient parts with white or black chalk on one of the proofs, and then endeavouring to make the plate similar by further scraping, or by relaying the ground with a small tool made for this particular purpose, where too much of the roughness has been effaced.

A third method of engraving consists in corroding the various lines by means of aquafortis, the remaining parts of the plate being defended from the action of the acid by being covered with a thin stratum of a composition which resists its effects. This method is termed etching, and is employed both for preparing the outline in other styles of engraving, and also for filling in and

completing a picture; and the prints so produced resemble pen and ink drawings. This style is distinguished for the inimitable spirit and freedom of which it admits. The first stage of the process is the preparation of the plate, by covering it with a thin even film of the composition or *ground*, as it is termed, which is to protect it from the acid. This ground is a combination of asphaltum, gum mastich, and virgin wax, melted over a fire in an iron pot. A piece of this ground is tied on a piece of lustring for use, and another piece of silk is made into a dabber by tying a quantity of cotton wool in it. The copper-plate, secured at one corner by a hand vice, is to be held over a charcoal fire, and the silk containing the ground rubbed over until every part is covered by the melted composition; and before it cools, the silk dabber is applied in all directions, until the surface of the plate is thinly and equally varnished. When this is completed, several lengths of wax taper twisted together are to be lighted, and the plate being held in the left hand by the vice, the right holding the wax taper, is to be waved gently to and fro under the ground, carefully avoiding touching it with the wick, yet causing the flame to spread smoothly over the surface, which will render it perfectly black, smooth, and shining in a short time. The next object is to transfer the design to the ground, which may be done either by making a tracing with a black lead pencil, or with vermilion, upon thin paper, and applying it carefully to the plate, pass the plate through a rolling-press; or the back of the design may be rubbed with red chalk and fastened to the plate at the corners, and the outline then gone carefully over with a blunt tracer. The outline thus prepared is then gone over with an etching needle, which cuts through the ground; but particular care must be taken that the point of the needle, though taper, be rounded, so as to avoid the possibility of its tearing the surface of the copper, which would prevent the progress of the point, and ruin the plate when bitten. The different shades and tints are then worked up by the needle, the arrangement of the lines of which they are composed depending entirely upon the taste and judgment of the artist. When the etching is completed, the edges of the plate are surrounded by a high border of wax, so well secured that water will not penetrate between it and the plate. The best spirits of nitre must then be diluted with water, in the proportion of one part of the former to four of the latter, and poured upon the plate. In a short time numerous small air bubbles collect over every line traced by the needle through the ground; these bubbles are caused by the action of the acid upon the copper, and must be removed with a feather. When it is judged that the lighter tints are sufficiently corroded, the acid is poured off the plate, which is then washed, suffered to dry, and the light parts stopped out, as it is termed, that is, covered with a composition of turpentine, varnish, and lamp black, diluted so as to be used freely with a camel's-hair pencil; this prevents the aquafortis from touching these parts again. After this the acid is again applied until the next depth of tint is obtained, which parts are in their turn stopped out; and thus the process continues, alternately biting in and stopping out, until every gradation of tint is obtained. The ground is then removed by covering the plate with olive oil, heating it, and then wiping it with a piece of old linen dipped in spirit of turpentine, which effectually removes all remaining dirt. If upon proving the plate, any part should be found not sufficiently corroded, it must be rebitten, which is effected by applying the ground so carefully as not to fill in the lines, but merely to protect the surface of the plate; and then raising a border of wax round the parts to be rebitten, apply the acid as before. When the operations of etching and rebiting are entirely finished, nothing remains to be done but to examine the plate attentively, and improve it with the graver and dry point.

The last style of copper-plate engraving which we shall notice is the aquatinta. The prints from an aqua-tinted plate greatly resemble a neatly-tinted Indian ink drawing. This effect is produced by covering the plate with a thin coating of various substances finely granulated, which defend it from the acid where they cover it, whilst the interstices amongst the particles or grains are corroded. The first step is to lay an etching ground, and to bite in lightly the outline, after which the plate is cleaned and polished with whiting,

previous to laying the grain. The best mode of laying the grain is as follows: common resin, gum mastich, or Burgundy pitch, is dissolved in highly rectified spirits of wine of the best quality; each of these substances produce a different description of grain, of which that from resin is the coarsest; but they may be mixed in such proportions as the artist prefers, who, to satisfy himself on this point, should try the grain of each proportion on useless slips of copper. Having obtained a solution to his mind, it must remain undisturbed until every impure particle has subsided, when it is poured upon the plate, which is held slightly slanting, until the most fluid parts run off, after which it is laid to dry, in the progress of which the resin granulates, and adheres firmly to the surface. The grain being thus laid, the various tints are obtained by biting in and stopping out, as in etching.

Another style of engraving has been introduced within these few years, called *machine engraving* or *ruling*, in which the lines are ruled with a diamond point on an etching ground, by means of a machine invented for the purpose by the celebrated Lowrie. This machine is capable of producing lines straight or waved, and either parallel or converging to any given point, as also parabolas, hyperbolas, and most other geometrical curves and circles varying from a point to a five-feet radius. The lines thus ruled are afterwards bitten in, in the usual manner, as in ordinary etching. This style is now universally employed for architectural and mechanical subjects, as also for putting in the buildings and skies in the works of line engravers.

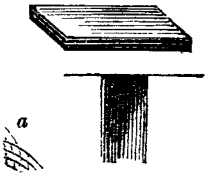
Steel Engraving, as we have already said, is extensively employed in the illustration of works of which very large editions are printed, on account of the durability of the steel plates, which is so great, that artists' proofs have sometimes been taken after 20,000 impressions have been thrown off, whereas a copper-plate will generally require touching after 1500 or 2000 impressions. But before steel can be cut by the graver it requires to be softened, by depriving it of a portion of its carbon, which is effected by imbedding the steel to the depth of half an inch on all sides in a bed of pure iron filings, contained in a cast iron box with a well closed lid. In this box the steel is to be exposed for four hours to a white heat, after which it is to be suffered to cool very slowly, which is best effected by shutting off all access of air to the furnace, and covering the box with a layer of fine cinders to the depth of six or seven inches. After the steel plate has been engraved, (which engraving may be in any of the styles practised on copper,) it requires to be hardened or reconverted into steel, which is effected by the following process: a suitable quantity of leather is reduced to charcoal, by exposing it to a red heat in an iron retort for a sufficient length of time; a cast iron box, whose cavity is about an inch greater than the thickness of the steel plate, is then to be filled with this charcoal reduced to a fine powder, and being covered with a well-fitted lid, it is to be exposed to a heat somewhat above a red heat, until all the volatile or evaporable parts are driven off from the charcoal. The lid is then removed, and the plate immersed in the charcoal, as nearly as possible in the middle, so as to surround it on all sides with a stratum of uniform thickness. The lid being replaced, the box must remain in the degree of heat before described, from three to five hours, according to the thickness of the plate. After remaining in the fire the requisite time, the plate is taken from the box and plunged immediately into cold water, from which it must be withdrawn before the hissing noise has ceased; but the precise point for this cannot be explained in words, and can only be learned by actual observation. The plate is then to be immediately laid over a fire, until its temperature is raised to that degree that smoke would arise upon rubbing the surface with tallow, when it must be again plunged into water, where it remains until the hissing sound becomes somewhat weaker than before. The process of heating and cooling is then to be twice repeated, after which, the surface of the plate is to be cleaned, and the temper finally reduced by heating it over a fire, until it acquires such a shade of colour as denotes that the steel is of the fit quality for the required purpose. For the process above described for softening and then rehardening steel plates, we are indebted to Mr. Perkins, it constituting an important branch

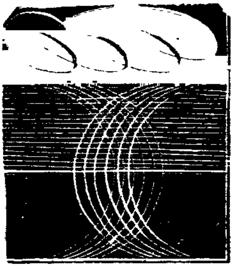
of an art invented by that gentleman, and to which he has given the name of Siderographia. By means of this truly wonderful invention, not only are engraved steel plates obtained, whose durability is unknown, (since Mr. Perkins states that he has taken 500,000 impressions from one plate,) but a plate being engraved, other plates may be produced from it, which shall be fac similes of the original. The method by which this astonishing effect is obtained is as follows: A steel plate is engraved or etched in the usual way; it is then hardened. A cylinder of very soft steel, of from two to three inches diameter, is then made to roll backwards and forwards on the surface of the steel plate, until the whole of the impression from the engraving is seen on the cylinder in relievo; after this cylinder has been hardened, it is made to roll backwards and forwards on a copper or soft steel plate, and a perfect fac simile of the original is produced of equal sharpness. But not only is perfect identity thus obtained, but the two styles of work, viz. copper-plate printing and letter-press may be beautifully combined, by means of the process of transferring and retransferring. This invention is admirably adapted to the prevention of forging bank notes, as by this means several first rate artists may be employed at one time to produce portions of a plate in detached parts, which may afterwards be combined and arranged in any order to produce a single plate, and before the note could be imitated by forgers it may be called in and a new note issued, consisting of the same parts differently arranged; the principle, also, offers various other modes of defeating attempts at imitation. The invention has accordingly been very extensively patronized by the banks in America from its outset; and at the present time the notes of most of the provincial banks in this country are produced by this process, some of them presenting the most beautiful specimens of the art of engraving ever witnessed. The bank of England, however, for reasons which are variously stated, has declined availing itself of the advantages which the plan holds out, and after going to an expense of more than 30,000*l.* in endeavouring to improve the quality of its notes, and to render them more difficult of imitation, still continues to issue the same wretched description of notes as have been so extensively and successfully counterfeited for many years past.

Wood Engraving is a process which is the reverse of copper-plate engraving, for in the latter, the incisions made in the metal receive the ink and print the design, while in the former, the raised parts form the design, receive the ink, and transfer the subject to the paper. Accordingly, in engraving a block of wood, the subject of which is to be represented by black lines, all those parts of the space occupied by the design, which are not drawn upon, are entirely cut away, whilst all the permanent lines of the drawing are left untouched by the graver, as shown in the subjoined profile sketch of a face. In work of this kind it is obvious that the engraver can easily produce a perfect fac-simile of the artist's drawing; in fact, his manual skill only is exercised to leave the lines of the design untouched, by carefully cutting away all the wood, and so deep that no other part of the block shall take the printer's ink from the dabber or roller, and that the paper in printing shall not reach the sunken parts. The process of clearing away the wood without damaging the lines of the drawing, is, of course, a nice operation; nevertheless, a learner in the space of two or three months acquires such dexterity with his little tools, that he cuts away nearly as fast as he can move his hand or fingers. Before, however, the engraver commences to "clear out" his work he "outlines it," which consists in carefully running a very sharp narrow-pointed graver along both sides of the lines of the drawing; this insures more accuracy and clearness in the subsequent operation, and to prevent the back of the graver from injuring the lines of the design, the engraver occasionally in difficult parts defends the lines by covering them with a thin piece of metal, which he holds down upon the work with the fingers of his left hand.

A much easier, and therefore cheaper mode of engraving on wood, is to make white lines on a black ground, as represented in the engraving on the next page.

In this case the block of wood is supposed, as in the former case, to have the profile drawn upon it, but instead of leaving the artist's lines upon the wood, he cuts them away alone, leaving the rest of the wood the same true plane it was before. The latter, therefore, receives the ink, and delivers it upon the paper, while the incisions, taking up no ink, leave their traces like white lines upon the paper. This mode of engraving on wood is, therefore, analogous to that upon copper plates, but the inking is different; as in the latter case the ink is rubbed into the lines or incisions, leaving the surface clean, and therefore the lines only of the copper plate are imprinted. The taste of a wood engraver is most exercised in softening the shadows and graduating the lights of his subject. A consideration of the following sketch will explain to the reader the principle upon which the engraver works. In the upper figure the strong light upon the top of it is produced by first cutting down in mass the upper surface at that part, by shelving or inclining the sides to the cavity made, so that when the parallel straight lines or tint is cut, their extremities become so extremely fine and tapering, that they can scarcely receive or deliver any ink, by their being sunk below the plane of the other parts. In the distance it will be noticed that the lines are very near together, to give the effect of distance, while those in front are comparatively wide apart, to give the effect of nearness. These different spaces are produced by gravers of different breadths of point. For this purpose the engraver provides himself with six or eight tinting gravers, which he numbers from 1 to 6 or 8, taking them up and changing them in his work as the subject requires. In the figure underneath, it will be seen that a strong light and a very deep shadow are brought very near together, but without offending the eye by too great abruptness. This is effected by continuing the white lines of the light part by lines of diminished thickness over the black or solid part, with a fine graver. A very close imitation of copper engraving may be made upon wood, so as to have great force and clearness in some kind of subjects, but can only be afforded by the engraver when he is duly paid for the great extra labour attending it. This consists in crossing the lines in the manner shown by a little bit at *a*, in the bottom corner of the preceding figure. The diamond-shaped pieces are every one picked out by the graver, and these, in some fine wood engravings, are extremely minute; nevertheless, the lines, however fine, are left clear and unbroken. To show the freedom, ease, rapidity, and consequent cheapness with which white lines may be executed upon a black ground, we have added the annexed illustrated cut, which was executed by an expert engraver in the space of three or four minutes. The wood made use of is mostly box, the best of which comes from Turkey. The tree is cut into slices transversely to the grain, and then rendered to a true plane and smoothed. On this fine compact surface the subject is drawn, either with black lead pencil or with Indian ink; but the latter is preferable (except for works of high finish), as it is not so liable to be effaced during the process of engraving. The art of engraving on wood is coeval with the art of printing, in Europe, the earliest books being printed from wooden blocks, each block comprising a page, as is the method at the present day in China, in which country the art, it is said, has been practised so far back as the christian era. After flourishing for a time in Europe, the art seems to have fallen into neglect, from which it was first rescued in England by the celebrated Bewick, since whose time it has risen gradually in repute and eminence, and now occupies a respectable station amongst the fine arts. The superior utility of wood engraving consists in the great durability of the blocks, but more especially in the peculiar advantage it





possesses of ranging with type, and being printed with it; which renders it particularly adapted for the illustration of mathematical and mechanical subjects, as the necessary diagrams and figures can be introduced in the body of the letter press, wherever it is most convenient for the elucidation of the subject. The blocks may likewise be stereotyped along with the type, as is now very generally practised with standard works.

ENTABLATURE, in Architecture, is that part of an order of a column over the capital; and comprehends the architrave, frieze, and cornice. Mr. Nicholson, author of *The New Practical Builder*, says, "In buildings upon magnificent scales, projections, similar to the entablatures just mentioned, are carried round the edifices, and, where the expenses are limited, along the front only: these projections are also termed *entablatures*." In this sense the term is applied by engineers to similar parts of the framing of machinery wherein architectural designs are introduced.

EPICYCLOID, in Geometry, a curve generated by a point in one circle, which revolves about the circumference of another circle. They are distinguished into exterior and interior epicycloids. An exterior epicycloid is formed by revolution of a generating circle upon the convexity of the quiescent circle; and an interior epicycloid is formed by its revolution along the concavity of the quiescent circle. A curious property of the latter description of epicycloid is, that when the diameter of the generating circle is equal to the radius of the quiescent circle, the epicycloid described is a right line equal and coincident with the diameter of the latter. Mr. Murray, of Leeds, applied this property to obtain a rotatory motion of the fly-wheel of a steam engine directly from the piston rod, without the intervention of a connecting rod. Epicycloids have been recommended by many eminent mathematicians as the best curve for the teeth of wheels; but in practice they are usually formed of circular arcs, as these work very well, and are easier of construction.

EQUATION, in Algebra, is an expression in which two quantities, differently represented, are put equal to each other by means of the sign = placed between them, as $3\,ab=d$.

EQUILIBRIUM, in Mechanics, signifies an equality of forces in opposite directions, whereby the body remains at rest, or in equilibrio; in which state the least additional force being applied on either side, motion will ensue.

EQUIVALENTS, Chemical. A term happily introduced into chemistry by Dr. Wollaston, to express the system of definite ratios in which the corpuscular objects of this science combine, referred to a common standard of unity. The two grand laws of chemical combination are, 1st, The general reciprocity of the saturating proportions; and 2d, The definite proportions in which bodies combine; and if any substances are capable of combining in more than one proportion, such combinations are always multiples, or submultiples of one of the proportions. The first of these laws was discovered by Richter, in 1792, who inferred it from the remarkable and well established fact that two neutral salts, in mutually decomposing each other, give birth to two new saline compounds, always perfectly neutral. Thus sulphate of soda being added to muriate of lime, will produce perfectly neutral sulphate of lime and muriate of soda. From this he concluded that the quantities of two alkaline bases adequate to neutralize equal weights of any one acid, are proportional to the quantities of the same bases requisite to neutralize every other acid. For example: 6 parts of potash, or 4 of soda, neutralize 5 of sulphuric acid; and 4.4 of potash neutralize 5 of nitric acid. Therefore to find the quantity of soda equivalent to the saturation of this quantity of nitric acid, we need not make any experiment, but merely compute it by the proportional rule of Richter. Thus—as 6 : 4.4 : : 2.93, the weight of soda required to saturate 5 parts of nitric acid; and this proportion of 6 to 4, or 3 to 2, will pervade all the possible saline combinations of these bases, so that it will require only two parts of soda to saturate as great a quantity of any acid as could be saturated by three parts of potash. The doctrine that bodies combine chemically in certain definite proportions, was first promulgated by Dr. Higgins, in his *Comparative View of the Phlogistic and Antiphlogistic Theory*, published in 1789. This doctrine was

subsequently maintained by Mr. Dalton, in his *New System of Chemical Philosophy*, first framed about the year 1803, and published in 1808. In this work Mr. Dalton fully establishes the proposition that bodies do not combine in all proportions, as Berthollet maintained, but that the different compounds of the same principles proceed in successive proportions, each a multiple of the first. This proposition has been further illustrated and confirmed by the researches and reasonings of the most eminent chemical philosophers, and is now universally admitted to be true. In the first part of the *Philosophical Transactions*, appeared Dr. Wollaston's description of his scale of chemical equivalents; an invention which has contributed more to facilitate the general study and practice of chemistry, than any other invention of man. This singularly useful contrivance consists of a flat ruler, about 2 inches wide and 18 inches long, on which a list of substances are arranged on one or other side of a logarithmic line of numbers, in the order of their relative weights, and at such distances from each other that the series of numbers placed on a sliding scale can at pleasure be moved, so that any number expressing the weight of a compound may be brought to correspond with the place of that compound in the adjacent column. The arrangement is then such, that the weight of any ingredient in its composition, of any reagent to be employed, or precipitate that might be obtained in its analysis, will be found opposite the point at which its respective name is placed. For example:—If the slider be drawn upwards till 100 corresponds with muriate of soda, the scale will then show how much of each substance contained in the table is equivalent to 100 of common salt. It shows with regard to the different views of this salt, that it contains 46.6 dry muriatic acid, and 53.4 of soda, or 39.8 sodium, and 13.6 oxygen; or if viewed as chloride of sodium, that it contains 60.2 of chlorine, and 39.8 sodium. With respect to reagents, it may be seen that 283 nitrate of lead, containing 191 of litharge, employed to separate the muriatic acid, would yield a precipitate of 237 muriate of lead; and that there would then remain in solution nearly 146 nitrate of soda. These, and many more such answers, appear at once by bare inspection, as soon as the weight of any substance intended for examination is made by motion of the slider to correspond with its place in the adjacent column. Dr. Wollaston took, as his standard or unity, oxygen, from its almost universal relation to chemical matter, and determined the equivalents of other substances by their relation to this standard. Sir H. Davy proposed as unity, hydrogen, which is the lightest of all known substances, and which, therefore, seems preferable as the basis of the scale, since the equivalents of all other substances must necessarily be expressed in all numbers without fractions; and this scale has, accordingly, been extensively adopted.

ERMINE. A fine description of fur, obtained from the skin of an animal of the same name.

ESSENCES. Several of the volatile or essential oils are called essences by the perfumers.

ESSENTIAL OILS, (called also *volatile* and *ethereal*,) are distinguished from fixed or fat oils, from the circumstance of their rising in distillation at temperatures below that of 320° Fahr. by themselves. They are mostly obtained from odoriferous vegetable substances, although some of the principles are found in animal matter. In different vegetables these oils are found variously lodged,—sometimes in the bark, as in cinnamon; sometimes in the root, as in the plant that yields the true camphor; sometimes in the wood, as in the cedar; sometimes in the leaves, as in mint, balm, &c.; sometimes in the flowers, as in the carnation and rose; sometimes in the rind, as in the orange and lemon; and, in a great variety of instances, in the seeds or fruit. The plants should be collected at the time their scents are the most powerful, and in most instances it is preferable to dry them previous to distillation, to get rid of some of the acid juices of the sap of the plant, which, by enabling the water with which they are distilled to dissolve more of the oil than it otherwise would, would diminish the produce. The drying of the plants should, if possible, be in the sunshine, but where this is not practicable, it should be effected as quickly as possible on a kiln. Woods must be reduced to shavings; barks, and similar

substances, to a gross powder; and these in general require to be soaked for some days before they are distilled, in water sharpened with salt, or a little muriatic acid. The still, if of copper, should be well tinned inside, and have a low head, that the oil may not have to rise high. The old alembic answers well, with the simple mode therein adopted of condensing at the capital or head, either by a small reservoir of water fixed thereon, or by enveloping the head with flannel, and allowing water to drip upon it. No more water should be added than is necessary to bring over the oil, and prevent the matter from burning in the still; hence, the goods should be first floated with water, and then more added by weight or measure, to determine the necessary quantity. In goods that yield their oil easily, about six times their weight is sufficient; but in others which yield their oils with difficulty, as the woods, about ten times their weight must be added. The distillation is conducted with a quick fire, until the quantity of water that was added is come over; and if the last portions bring over any oil with them, the fire is slackened, and the distilled water returned into the still, and brought over a second time; sometimes it is found necessary to distil it a third time. As some oils congeal at a low temperature, it becomes necessary that the condenser be not kept so cold as to produce that effect, but at that temperature by which the oils would preserve their liquid form, in order that they may flow out into a receiver. And as it is difficult to clean out the convoluted worms of ordinary condensors, those with straight or zigzag tubes are preferable where more than one kind of oil is made, otherwise the odour of one would be mixed with another. The quantity of oil which comes over being extremely small in comparison with that of the water, it is proper to have a receiver that will allow the water to run off into another vessel, while it retains the oil. The water used in a previous distillation may be advantageously used in a second, and sometimes a third distillation, to save that portion of the oil which always combines with fresh water. It is, however, to be observed, that by frequent cohobation, the water acquires acid properties, and then takes up a larger quantity of oil, and diminishes the produce. Roses should be distilled with their green flower cups, and be torn open with the nails, as the liquid or scented oil is lodged in a cell at the claw of each petal. By adding a little muriatic acid to the water, and digesting for a few days, the produce is doubled. The essential oil of bitter almonds requires particular treatment, and the distillation should be conducted in the open air, to prevent the deleterious effects of its vapours, which cause severe head-ache and fainting to all persons within its influence. The usual process consists first in pressing the almonds, to separate the fixed oil, and then grinding the resulting oil cake to a coarse powder. Thirty pounds of this powder is then to be distilled with eight gallons of water, until the whole is come over, when there will be found floating about three-quarters of an ounce of essential oil; this is to be taken off, and then as much salt as the water will dissolve is to be added to it, and about a gallon of this being distilled, a further produce of four or five ounces of the essential oil will result therefrom. The essential oil of turpentine, called also spirit of turpentine, is prepared by distilling turpentine in iron stills with a condensing apparatus, until the drops of oil begin to grow coloured. One hundred-weight of turpentine yields from twelve to twenty pounds of oil; the product is found to be greater in proportion to the slowness of the operation. For medical purposes the turpentine is either distilled with water, or rectified with it, but as a portion of water thus combines with it, it is not adapted to painters' use. The essential oils of aniseed, camomile, caraway, cassia, cinnamon, cloves, dill, juniper berries, mint, nutmegs, penny-royal, peppermint, rue, sassafras, savine, and wormwood, are used in medicine as carminatives and stimulants. Those of aniseed, caraway, cassia, cinnamon, cloves, juniper, and pepper, are used in compounding the cordial waters of the spirit dealers. A third class, as those of balm, citron flowers, lavender, orange flowers, roses, rosemary, sandal, thyme, are used to scent and flavour spirits of wine, to make what are called toilet waters, as eau de Cologne, Hungary water, &c. which are employed as cordials. The essential oils of balm, calamus aromaticus, camomile flowers, caraway seeds, hyssop, lavender

flowers, marjorum, milfoil, parsley, rosemary, sage, sassafras, thyme, are used to scent soaps.

ETHER. See ÆTHER.

EUDIOMETRY. The measurement of the quantity of oxygen contained in atmospheric air, or, indeed, in any gas in which it is not intimately combined, is named eudiometry, and the instrument by which it is performed is named the eudiometer. There are two modes of effecting this; either by presenting to the oxygen any substance having a strong affinity for oxygen, or by exploding it with hydrogen in a strong glass vessel by means of the electric spark, and in either case estimating the quantity by the decrease in the bulk of the gas. In the first method, the substances usually employed to absorb the oxygen, are either phosphorus, sulphuret of potash, or nitrous gas, which latter substance, when used according to the directions of M. Gay Lussac, seems preferable to any other; these directions are as follows:—Take a very wide tube or tumbler, for example, invert it in water, and having introduced into it 100 parts of the air to be examined, pass into it 100 parts of nitrous gas. There is instantly exhibited a red vapour, which is nitrous acid gas, and which being very soluble in water, disappears speedily without agitation, and after a minute at most the absorption is complete; then transfer the residuum into a graduated tube, and it will be found that the absorption is almost uniformly 84 parts, provided atmospheric air was used; and as nitrous acid (the resulting compound) consists of three volumes of nitrous gas and one volume of oxygen, one-fourth of the absorption, equal 21 parts, indicates the quantity per cent. of oxygen. M. Gay Lussac shows by numerous experiments, the accuracy of the above process in varied circumstances. There is this great advantage attending it; that the proportion of oxygen gas being estimated by an absorption four times greater than its own volume, the errors of experiment are reduced to one-fourth. The analysis of combustible gases, and the supporters of combustion, reciprocally by explosion with the electric spark, furnishes, when it can be applied, one of the most elegant and speedy methods of chemical research; but is attended with some danger, from the liability of the tube to burst, if a close tube is used, or with a risk of failure from the ejection of the mercury when the tube is merely sealed by that fluid. This has given rise to several modifications of the apparatus, most of which are somewhat complex and costly; but that invented by Dr. Ure, and communicated by him to the Royal Society of Edinburgh, is at once simple, cheap, and effective. It consists of a glass syphon, having an interior diameter of from two-tenths to four-tenths of an inch. Its legs are nearly of an equal length, each being from six to nine inches long. One end is open and slightly funnelled; the other end is hermetically sealed, and has inserted near it by the blow-pipe two platina wires. The outer end of one wire is incurvated across, so as nearly to touch the open end of the tube; the outer end of the other wire is formed into a small hook, to allow a little spherical button to be attached to it when the electric spark is to be transmitted. To use it, the whole syphon must be filled with water or mercury, then plunge the open leg into a pneumatic trough, and introduce into it any convenient quantity of the gases from a glass measure tube, containing them previously mixed in determinate proportions. Then, applying a finger to the orifice of the syphon, remove it from the trough, and transfer the gases into the sealed leg, by holding the syphon leg uppermost. Then bring the mercury to a level in both tubes, by adding or displacing a portion, and note carefully the volume of gas in the sealed leg, which should be graduated to one hundredth parts of a cubic inch. Then applying again the fore finger to the orifice, so as also to touch the end of the platina wire, bring the pendant ball or button to the electric machine, and transmit the spark. After the explosion, on gradually sliding the finger to one side, and admitting the air, the mercury will rise in the sealed leg more or less above that in the other; then pour in mercury till the equilibrium be restored, and read off, as before, the bulk of the remaining gas, and the difference of the two volumes will denote the true quantity of oxygen, without requiring any reduction or allowances. So perfectly is the shock of the explosion deadened

by the elasticity of the air confined between the finger and the surface of the mercury in the open end of the tube, that nothing but a slight push or pressure at the tip of the finger is felt, even when the included gas is in considerable quantity and of a highly explosive nature; and the projection of the mercury or displacement of the gas is obviously impossible.

EVAPORATION. A term generally used to signify the dissipation of the volatile parts of a compound body, whether caused by the action of the sun and atmosphere, or by artificial means; although some authors restrict the use of the word to the former case, and employ the term vaporization in the latter. A distinction is likewise drawn in the case where the volatile parts are the objects of the process, which is then termed distillation; but the fixed parts, or the residuum, are the products sought by evaporation. The vessels are accordingly different, evaporation being commonly carried on in open shallow vessels, and distillation in vessels nearly closed from the external air. The degree of heat must be duly regulated in evaporation. When the fixed and more volatile matters do not differ greatly in their tendency to fly off, the heat must be very carefully adjusted; but in other cases this is less necessary. As evaporation consists in the assumption of the elastic form, its rapidity will be in proportion to the degree of heat and the diminution of the pressure of the atmosphere; a current of air is likewise of service in this process. Dr. Ure, in his *Chemical Dictionary*, mentions the following method of evaporating liquors, as being practised in some large alum manufactories. A water-tight stone cistern, about three or four feet broad, two feet deep, and from twenty to forty feet long, is covered over by a low brick arch. At one extremity of this tunnel a grate is built, and at the other a lofty chimney. When the cistern is filled, and a strong fire kindled in the reverberatory grate, the flame and hot air sweep along the surface of the liquor, raise the temperature of the uppermost stratum almost instantly to near the boiling point, and draw it off in vapour. The Doctor observes, that the great extent, rapidity, and economy of this process recommend it to general adoption on a large scale.

More recently, Mr. Jacob Perkins has obtained a patent for a novel mode of forming steam of very high pressure, by confining the water under mechanical pressure, in a boiler properly constructed for the purpose and intensely heated;

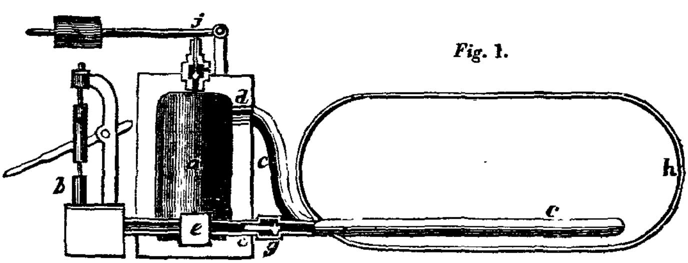


Fig. 1.

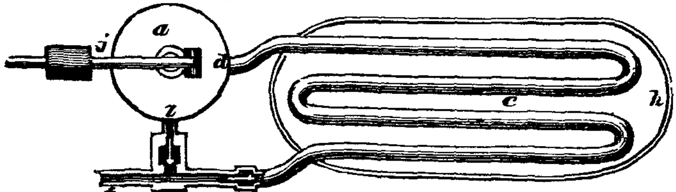


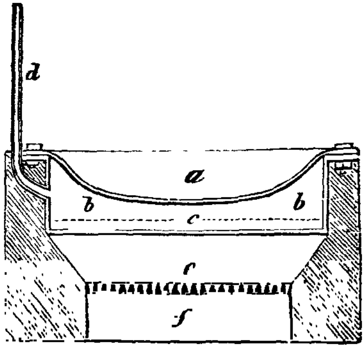
Fig. 2.

and subsequently he obtained another patent for an adaptation of that apparatus for the evaporating of water and other fluids. For this purpose the high pressure steam is projected from the generator through pipes which circulate through the evaporating pans or boilers; and such an arrangement is

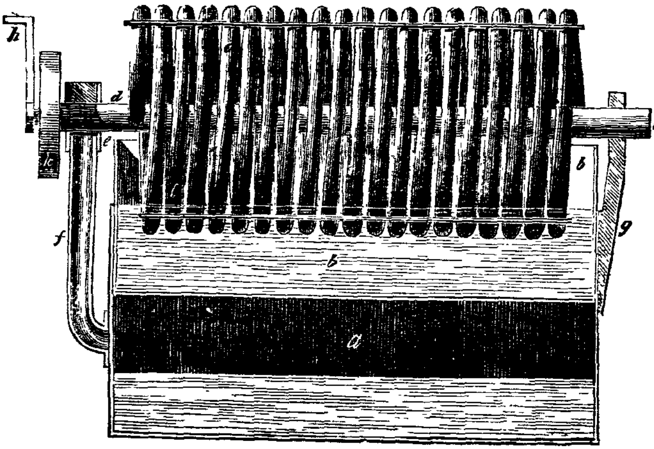
made, that the water produced by the condensation of the steam is returned into the generator by means of valves and a force pump, the steam or water being always under mechanical pressure. The preceding engravings give a sectional elevation and a plan, and the same letters of reference apply to similar parts in each figure. *a* is the generator; *b* the forcing pump; *c* a pipe opening into, and projecting from the upper part of the generator at *d*, and opening to, and projected from the lower part of it, opposite to *e*; *f* is a pipe leading from the pipe *c* to the forcing pump; *g* is a valve; *h* a vessel, containing the liquid to be boiled or evaporated; and *j* a safety valve. At *l*, in the plan, is a valve opening into the generator; it is not seen in *Fig.* 1, but is in a line with the part marked *e* in that figure. When steam is admitted from the generator into the pipe *c c*, it becomes condensed in heating the surrounding fluid in the vessel *h*, and collects in the form of water at the valve *g*. Upon raising the handle of the forcing pump, the valve *g* opens, and the water fills that portion of the pipe marked *f*, between the pump and the valve *g*, the pressure in the generator keeping the valve at the opening *l* shut. When the handle of the force pump is depressed, the valve *g* shuts, and the water being prevented, in consequence, from returning into the pipe *c*, necessarily forces open the valve at *l*, and is returned into the generator; and this operation is of course successively repeated at every stroke of the piston rod of the pump.

Messrs. Beale and Porter's patent method of applying heat for the purposes of evaporation, consists in the use of various fluids as media for the communication of heat, which rise in vapour or boil at different degrees of temperature; so that one substance may be chosen as proper for one process, and another substance or combination of substances may be employed as more suitable for other processes, the nature of these substances being such that, under the ordinary pressure of the atmosphere, each will indicate a known and unvarying degree of heat at its boiling point, which may be communicated to any substance exposed to its action. Amongst the numerous substances suitable for heating media, are the following: Spirits of turpentine, which boils at 316° Fahr., and naphtha, which boils at 400° Fahr.; and by distilling coal tar, and collecting the products at different periods, various other bodies are obtained, which will furnish different degrees of heat ranging between 400° and 700° Fahr. By this arrangement it was expected that the maximum degree of heat would be always and altogether independent of accident or want of skill, so that no injury from burning could possibly arise, except through the employment of an improper medium, which, as fluids may be chosen whose boiling points vary between the range of 200° and 700° Fahr., need never occur. The mode of applying this principle to boiling or distilling, is, by using a double vessel, having one part placed within the other, so as to leave a small intermediate space. Into this space the substance intended to form the medium must be introduced, in sufficient quantity to cover the *flat* bottom of the outer vessel, to such a depth as to secure it from injury by means of the fire. When this fluid is made to boil, it will give off vapour of the same temperature, which, as it comes in contact with the surface of the inner vessel, will part with its heat thereto, and, resuming the fluid form, will fall again to the bottom of the vessel, to be again vaporized; and so on, in a constant alternation of evaporation and condensation. To keep up a communication between the fluid medium and the atmosphere, and avoid thereby all tendency to rupture or explosion, a tube, open at both ends, is introduced into the intermediate space between the vessels. Should there be gross mismanagement of the fire, some portion of the vapour would be forced up this tube; it is therefore made to pass through a condenser, the action of which will return the fluid to the double vessel, so that little or no waste of the fluid medium will be sustained. This mode of evaporating has, we understand, been applied with great advantage in the refining of sugar,—a substance so liable to injury from an excess of heat, that the most complex and expensive plans have been resorted to in order to avoid the danger of burning. The plan has likewise been successfully adopted in several large medicinal laboratories, and is equally valuable to distillers, dyers, and, in short, almost every process in the arts where a steady uniform temperature is of importance.

The diagram here given will show the great simplicity of the plan, and the little chance there is of injury to the apparatus from the fire, as it comes in contact only with a surface always protected by a fluid which rapidly absorbs and carries off the caloric. The engraving represents the apparatus as adapted to the purpose of sugar refining. *a* the evaporating pan; *b b* the outer pan, containing *c*, the fluid medium, represented by dotted lines, and which, for the purposes here described, is a modified product, by distillation of coal tar, which furnishes vapour at the fixed degree of 350° Fahr. *d* the breathing pipe, which, in the event of injudicious firing, will serve as an outlet and condenser for such portion of the vapour as may not otherwise be condensed by the comparatively cold surface of the evaporating pan *a*; *e* an ordinary furnace; *f* the ash pit.



Air, it is well known, has a great affinity for vapour, and large quantities of water are evaporated by the process of nature, even at the temperature of the atmosphere, wherever a large surface is exposed to the action of the air. Taking advantage of this fact, Mr. Cleland has contrived a new and singularly elegant method of evaporating the aqueous parts of syrups and saline solutions. The principle of the invention consists in continually exposing a thin *film* (if the expression may be allowed) of the liquid to the joint action of heat and air, and by that means effecting a rapid evaporation. The apparatus consists of a convoluted worm of great length, heated by steam in the interior, which is made to revolve horizontally upon its axis, partly immersed in the liquid under evaporation, which is thereby constantly taken up by it in the thinnest possible



stratum; and being in contact with the hot surface of the metal, the aqueous portion of the matter is quickly formed into steam, and carried off by the surrounding air. *a* is the boiler or vessel affording steam, which may therefore be imagined as set over a furnace; *b* is a shallow vessel, containing the syrup to be concentrated, and so placed upon the boiler as to form the top or cover to it; *c c* is the worm, supported by stays upon an axis *d d*, which has a cavity at

each end communicating with the worm. One end of *d* is supported in a stuffing-box *e* upon a hollow arm *f*, which communicates with the boiler, and is pierced with numerous small holes in that part which turns in the stuffing-box; the other end of the axis *d* is supported by a solid arm *g*, and is open at the extremity for the emission of the steam after it has passed through the numerous coils of the worm. The axis may be turned by a winch *h*, or by a pulley *k*, or receive its motion from any convenient prime mover. By this excellent arrangement it will be seen that the steam in the boiler acts upon the bottom of the evaporating pan, and raises the temperature of its contents; at the same time it passes by the hollow arm *f* through the small apertures in the axis *d* into the worm *c*; herein it traverses through all the turns, and escapes finally at the opposite end of the axis into the atmosphere. The lower part of the worm reaches to but a small depth in the syrup, and by turning the worm, every portion of it becomes covered with the liquid, and lying in contact with an extensive heated surface, vapour is given off, which is quickly absorbed by the surrounding atmosphere.

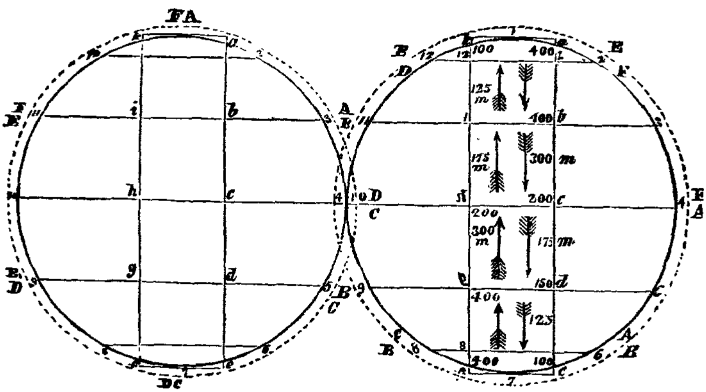
EVOLUTE, in the higher Geometry, a curve, which, by being gradually opened, describes another curve. It may be described mechanically by unwinding a string, to which is fastened a tracer, from off a cylinder or any other curve.

EXCAVATING MACHINES, for digging and removing earth in extensive excavations, have occupied the attention of many ingenious men, and various machines for the purpose have been proposed and tried with different degrees of success. The great difficulty appears to consist in adapting any peculiar arrangement of mechanism which shall be capable of digging into the various kinds of earth. Were it only to operate upon a uniform mass, like soft clay, the task would be comparatively of easy accomplishment. Mr. G. V. Palmer, of Worcester, appears to have devoted himself with great assiduity to the construction of an efficient excavating engine, and to have expended considerable sums in its attainment. In 1830 he took out his first patent "for a machine to cut and excavate earth," which we have perused at the Inrolment Office. This machine is designed, by the application of steam power, to loosen, dig up, and remove into a cart, earth from a canal or other cavity, and to move itself forwards as the excavation proceeds. In principle its leading arrangement resembles the dredging machines employed in clearing the beds of rivers and harbours; but it has several appurtenances, such as picks, for loosening the earth, cutters, for separating it, and scrapers, for filling it into the scoops or elevators, which convey it into the cart by which it is moved away. The machine is mounted upon four wheels, and gradually moves forward upon a temporary railway as the excavation proceeds. The moving power is applied to the axis of a fly-wheel, and to the same axis is fixed a drum or pulley, around which passes an endless pitched chain, that gives motion to another drum or pulley, which revolves in bearings fixed to the upper ends of two long cheeks or supports. Around this second drum passes another endless chain, which gives motion to a third drum or pulley, which is of a quadrangular figure, and turns on an axis in the lower ends of the long cheeks; to this last-mentioned chain are fastened a series of earth scoops, which are successively brought into operation in taking up the earth. So far the machine resembles the common ballast engine; we have therefore to describe how the several actions of picking, digging, and projecting the earth are effected. A third endless chain is actuated by the drum on the main axis, and gives motion to a spur-wheel, which drives another toothed wheel attached to the fore wheels of the carriage, which gradually advances it. By an ingenious system of levers, connected to a crank on the main axis, a row of pick-axes, a row of cutters, and a row of scraping shovels, are alternately brought into action. When the pickers have descended and loosened a portion of earth, the cutters succeed, and separate it from the mass, and this separated portion is immediately afterwards drawn forwards by the scraping shovels into the scoops, which, by the action of the machine, are brought into the required position on one of the sides of the revolving quadrangular drum; the filled scoops thence proceeding to the top of the machine by

the revolution of the attached endless chains, discharge their contents into a cart or waggon to be conveyed away. The same gentleman patented another engine for this purpose in 1832. This consisted of an excavating cart and plough united, to be worked by horses or other power. The cart wheels are made considerably wider than those in common use, and the interior portion of the ring of each wheel is made into a series of earth boxes; these earth boxes are made to open inwards, and also towards the centres of the wheels. Underneath the cart, immediately adjoining each wheel, is placed a plough, for raising and turning the earth into the boxes, as the cart is moved forwards; the wheels at the same time turning round, bring up the earth and deliver it into the body of the cart. When a sufficient load has been thus deposited in the cart, the ploughs are raised from the ground by means of a lever, and then the cart can be drawn in every respect as a common cart, to the place intended for the deposition of the excavated earth, where it is to be unloaded by withdrawing a pair of bolts, which allow the bottom of the cart to fold downwards sufficiently to permit the earth to escape. There are many circumstances where the application of excavating machinery of this kind might be employed to advantage. Under the head BARROW will be found some useful information relating to this subject, which we have repeatedly seen practised on the great scale.

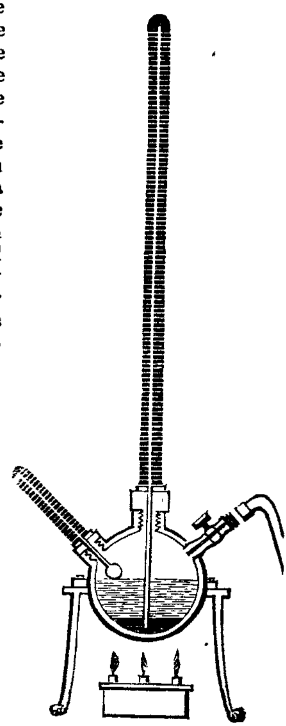
EXHALATION is distinguished from evaporation by some writers, as not applying to the raising of vapour in the ordinary sense of the word, but to subtle, dry effluvia, loosened, by the action of the sun, from minerals and other hard terrestrial bodies; that these exhalations ascend until their specific gravity equals that of the surrounding atmosphere, where, mixing with other vapours, they help to form clouds, and return to the earth in mists, dews, rains, &c.

EXPANSION, in Natural Philosophy, the enlargement or increase of bulk in bodies, chiefly by means of heat. This is one of the most general effects of caloric, being common to all bodies whatever, whether solid, fluid, or in the aeriform state. Metals expand in the following order, those that expand most being placed first:—zinc, lead, tin, copper, bismuth, iron, platina. The degree of expansion produced in different liquids varies considerably. In general, the denser the fluid, the less the expansion; water expanding more than mercury, and alcohol more than water. The various elastic fluids, or gases, on the contrary, all expand equally, the expansion being about one four hundred and fortieth part of their bulk at 32° Fahr. for every degree of heat. But elastic fluids are capable of expanding indefinitely without the application of heat, by the mere enlargement of the containing vessel; since whatever be its capacity, they must necessarily be equally diffused, and press with equal force in every part of it, the pressure being inversely as the bulk of the gas. This property of elastic fluids has been turned to great advantage in steam



engines, by admitting steam of high pressure into the cylinder during a portion of the stroke, and then shutting off the communication with the boiler; the

expansion of the steam in the cylinder carries the piston with a constantly decreasing force through the remaining portion of the stroke, by which mode of working the whole effect produced during the expansion of the steam is clear gain. Upon this subject Mr. J. Perkins, who has employed steam of greater expansive force than perhaps any other person, observes, that there is great economy in using very high steam expansively, and that the higher the steam can practically be used, the sooner it may be cut off. The *preceding* diagram shows (approximately) the gain in cutting off the steam at a quarter stroke. Let the piston, which is represented by the line *k* 1 *a* descend to *i b*, being one quarter of the stroke, with a constant force of 400 lbs. per square inch. At this point let the steam be cut off and expand to double its volume; when it arrives at *h c* it will be exerting a pressure of 200 lbs. per square inch, producing a mean pressure of 300 lbs. per square inch through the quarter stroke. Let the steam again expand to double its volume, and the piston will finish its stroke at *f e* at 100 lbs. per inch, giving a mean of 150 lbs. through the last two quarters; to which add 400=the pressure during the first quarter, and 300=the pressure during the second, and the sum will be 1,000, giving a mean pressure of 250 lbs. on the inch throughout the whole stroke. It will be seen that when the stroke is completed, the cylinder will be filled with steam of 100 lbs. pressure per square inch, which will be the same in quantity as though the steam had begun at a pressure of 100 lbs. and continue at that pressure throughout the stroke; but in this case the sum of the pressure through the four quarters would only be 400 lbs. so that by using the same quantity of steam expansively, there is a gain of 150 per cent. By employing two cylinders, the pistons of which act upon cranks at right angles to each other, a compensation is obtained for the varying pressure of the steam; for whilst one piston is at its greatest power, the other is acting with diminished power, so as to render the force exerted nearly the same throughout the revolution, as will be seen by the diagram.



The annexed figure represents an instrument for showing the expansive force of steam at different temperatures. At the bottom of a strong spherical vessel of brass is placed a quantity of mercury sufficient to fill the long vertical glass tube above; over the mercury is the water to be converted into steam, by a spirit lamp placed beneath. The long tube is submerged in the fluid, so as to nearly touch the bottom; on one side of this tube a thermometer is fixed in an inclined position, its bulk projecting towards the centre of the vessel. On the application of heat, the water is converted into steam, which, by its expansive force, presses upon the surface of the mercury, and impels it up the long tube, where its pressure is noted upon a graduated scale; at the same time, the height of the mercury in the thermometer shows the temperature of the steam.

EXPERIMENTAL PHILOSOPHY. That philosophy which proceeds on experiments, and deduces the laws of nature, and the properties and powers of bodies, and their action upon each other, from sensible experiments and observations. The business of experimental philosophy is to inquire into and investigate the reasons and causes of the various appearances and phenomena of nature, and to make the truth or probability thereof evident to the senses, by plain, undeniable, and adequate experiments, representing the several parts of the

grand machinery and agency of nature. Sir Isaac Newton, the greatest master in the science, lays down four rules by which to guide our inquiries into nature. 1st, More causes of natural things are not to be admitted than are both true and sufficient to explain the phenomena; 2d, and therefore, of natural effects of the same kind, the same causes are to be assigned, as far as it can be done, as of respiration in man and beasts; of light in a culinary fire and in the sun; and of the reflection of light in the earth and in the planets. 3d, The qualities of natural bodies, which cannot be increased or diminished, and agree to all bodies in which experiments can be made, are to be reckoned as the qualities of all bodies whatever; thus because extension, divisibility, hardness, impenetrability, mobility, the vis inertiæ, and gravity, are found in all bodies which fall under our own cognizance or inspection, we may justly conclude they belong to all bodies whatsoever, and are, therefore, to be esteemed the universal and original properties of all natural bodies. 4th, In natural philosophy, propositions collected from the phenomena by induction, are to be deemed (notwithstanding contrary hypotheses) either exactly or very nearly true, till other phenomena occur by which they may be rendered either more accurate, or liable to exception. This ought to be done lest arguments of induction should be destroyed by hypothesis. These four rules of philosophizing are premised by Sir Isaac Newton to his third book of the *Principia*, and more particularly explained by him in his *Optics*, where he exhibits the mode of proceeding in philosophy.

EXPLOSION, in Natural Philosophy, a sudden and violent expansion of an aerial or other elastic fluid, by which it instantly throws off any obstacle that may be in the way. It differs from expansion in this, that the latter is a gradual and continued power, whereas the former is always sudden and of only momentary duration.

EXPONENT, in Algebra, is a number placed over any power or involved quantity, to show to what height the root is raised; thus 2 is the exponent of x^2, and 4 is the exponent of x^4. or $xxxx$.

EXTRACT. Mixtures of several of the principles of vegetables, reduced by decoction either to a solid, or to the consistence of paste. The word is also applied by modern chemists to denote a peculiar substance supposed to be one of the immediate principles of vegetables, and the same in all when separated from any foreign admixture, except as the proportions of its constituent principles may vary.

F.

FACADE, or FACE, in Architecture, the side of a building in which is the principal entrance; also that exterior part of a building which is projected or advanced beyond the main body.

FACE GUARD. A kind of mask to defend the face and eyes from accidents in various chemical and mechanical processes. A guard intended to preserve the face, and particularly the eyes of smiths, founders, and others, from being injured either by the heat of the furnace or of red hot melted metal, or of fragments of metals dispersed by the hammer, is described in the *Transactions of the Society of Arts*. The guard is of two forms, either a *veil* of iron wire-gauze of a curved form, and fastened by a hinge to the front part of the hat; or a *mask*, more or less complete, with the eye-holes covered with wire-gauze. There is not much novelty in the invention itself, but there is in its application to persons exposed to the radiant heat of furnaces, whose eyes, it is well known, often become much injured thereby. The great utility of it for these purposes, has been testified by a number of persons who have recently adopted their use, and have expressed their surprise at the trifling heat which they, in consequence, felt upon their faces. The author of this invention, Mr. Callaghan, received a reward for it from the Society; and we have no doubt that its adoption by those classes of workmen for whose use it was designed, would prove highly beneficial to them.

FACETS, in Crystallography, the flat surfaces which bound the angles of crystals.

FACIA, or FASCIA. A broad flat projecting part of a building, as the bands of an architrave, larmier, &c.

FACTOR, in Arithmetic, a name given to the multiplier and multiplicand, as their quantities multiplied together constitute the product or *factum.*

FAKE. One of the circles or windings of a cable or hawser, as it lies disposed in a coil.

FAN. A machine used to agitate the air, and cause it to impinge upon other bodies to reduce their temperature. Those used for cooling the person are made of every variety of form and materials that fancy can invent; but they generally consist of a piece of paper, satin, or any other light fabric, cut semicircularly, and mounted upon several little sticks of wood, ivory, tortoise-shell, or the like. If the stuff be single, the sticks of the mounting are placed on the least ornamented side; if double, they are placed betwixt them. The paper is plaited in such a manner that the sticks may be alternately inward and outward. In the middle of each plait the sticks are cemented; all of which are cut exceedingly thin and delicate, and they are connected together at the end by a single rivet, by which the fan, as it is held in the hand, may be either folded up or expanded. The Chinese and East Indians excel in elaborate carving upon the fan sticks; but the elegance and taste displayed by our own artists upon the other parts, are unrivalled. The term fan is applied to those small vanes or sails that receive the impulse of the wind, and, by a connexion with machinery, keep the large sails of a smock windmill always in the direction of the wind; see WINDMILL. Also a rotative blowing machine, consisting of vanes turning upon an axis, used for winnowing corn. Similar apparatus is used to decrease the speed of light machinery, by the resistance of the air against the motion of the vanes.

FARINA implies generally vegetable flour. The flour of the Parisian bakers (which it may be presumed is chiefly, if not wholly, wheaten,) was ascertained by M. Vauquelin to consist of gluten 10.2, starch 72.8, sweet matter 4.2, gummy glutinous matter 2.8, and moisture 10, in 100 parts. The farina of many vegetables consists almost entirely of starch, as is the case with rice, arrow root, and the potatoe. The method of separating the farina from the latter root is described with figures under the word BREAD. A patent was granted in 1829, to Mr. Benjamin Goulson, of Pendleton, near Manchester, for "certain improvements in the manufacture of farina and sugar from vegetable productions." The specification explains it to consist in a method of converting dahlias, beets, carrots, mangel wurzel, and other roots, by the application of acid. After the roots have been well cleaned by washing, and cleared from their skins by rubbing or other process, they are to be sliced or grated, and steeped in a mixture of pure water and acid (the preference being given to sulphuric acid), in a ratio varying from two to ten pounds of acid (according to the roots operated upon,) to a hundred weight of roots. Those which possess the least natural sweetness will probably require the most acid. In this mixture the roots are to be kept till they become quite soft or pulpy, when they are to be washed with pure water till they cease to taste of the acid. They are next to be dried in the sun or in an oven, and then be ground into flour, and used for making bread, or other purposes for which wheaten flour is employed. To extract the saccharine matter from roots, Mr. Goulson employs a second dose of diluted acid, in the proportion of from two to ten pounds of the acid to a hundred weight of the farina thus obtained, and by this means the fibrous parts become macerated; after which the acid is to be neutralized and separated from the saccharine portion, which is then to be clarified by the usual processes; or the saccharine matter may, by continuing the first process, and using an additional quantity of acid, be obtained at once without first converting the roots into flour.

FARRIERY is the art of shoeing horses and administering to their diseases. See HORSE-SHOE.

FAT. Animal oil in a concrete state, deposited in minute cells in various

parts of the bodies of animals. The colour is white or yellowish; it is insipid, inodorous, insoluble in water and in alcohol, but it combines with alkalies and forms soap. It absorbs oxygen by exposure to the air, and becomes rancid, forming a peculiar acid, called the sebacic. It is decomposed by heat, producing the sebacic acid, an empyreumatic oil, and carbonated hydrogen, leaving a residuum of charcoal. Fat is oxidated by the acids, and it oxidates several of the metals, when they are combined with it in the form of an ointment. Some interesting information on the nature and properties of fat, and the mode of separating its constituent properties, will be found under the head CANDLE. See also SOAP.

FAT is also a name given to a measure of capacity, differing in different commodities. Thus, a fat of isinglass contains 3 to 4 cwt.; a fat of unbound books is four bales; a fat of wire 20 to 25 cwt; a fat of yarn 220 bundles.

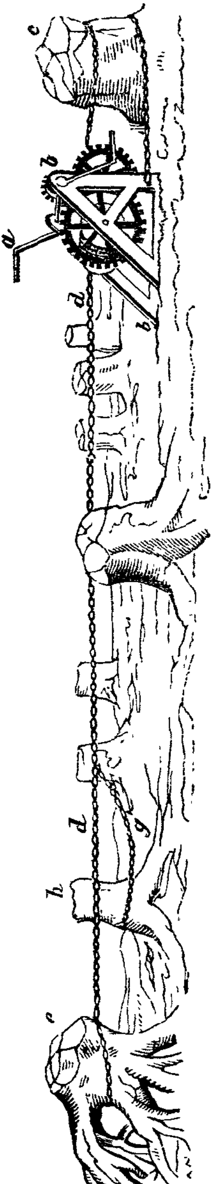
FATHOM. A measure of six feet, used to regulate the length of cables, rigging, &c., and to divide the lead or sound lines.

FEATHERS. A general name for the natural covering of birds. Chemically examined they are found to differ but little from hair or bristles. Mr. Hatchet boiled some feathers for a long time in water, but discovered no traces of gelatine; the quill is chiefly albumen. Feathers form a considerable article of commerce, particularly those of the ostrich, heron, swan, peacock, goose, &c. for plumes, ornaments, beds, pens, &c. Geese are plucked in some parts of England five times a year, and in cold seasons many of them die by this barbarous custom. Those from Somersetshire are esteemed the best, while those from Ireland the worst; but there are exceptions to this rule, for we have seen some Irish feathers equal to those imported from Dantzic and Hamburg, which attain the highest price in the market from their superior strength, that is, durable elasticity in the making of beds. Goose feathers are usually sorted into white and grey. The latter make equally good beds with the white, but their colour diminishes their value for sale to the extent of sixpence the pound in the best qualities. Those feathers denominated "poultry," which are from turkeys, ducks, and fowls, are of very inferior value; for although they are soft to the touch, they are too deficient in elasticity to make light or good beds. Wild duck feathers are soft and elastic, but the difficulty of curing them from the odour of the oil they contain, renders them less suitable than those of the goose. Irish feathers have obtained a bad character from the large quantity of foreign matter, particularly lime, with which they are *usually* mixed. A small portion of lime sprinkled amongst fresh feathers tends to their preservation, by combining with the oil they contain, while it also prevents the putrefaction of the small portions of animal fibre that occasionally adhere to them; but the Irish peasantry, or the small dealers in Ireland, with the view of imposition, *load* them to an injurious extent, which renders the cleaning of such feathers a work of time and difficulty. The following process of clearing feathers from their oil, and preparing them for use in making beds, was communicated to the Society of Arts several years ago by Mrs. Jane Richardson, whom the Society rewarded in consequence with the sum of twenty guineas. "Take, for every gallon of clean water, one pound of quicklime; mix them well together, and when the undissolved lime is precipitated in fine powder, pour off the clear lime water for use. Put the feathers to be cleaned into another tub, and add to them a quantity of clear lime water, sufficient to cover them about three inches, after they have been well immersed and stirred about therein. The feathers when thoroughly moistened will sink down, and should remain in the lime water three or four days, after which the foul liquor should be separated from them by laying them on a sieve. The feathers should be afterwards well washed in clean water, and dried upon nets, the meshes of which may be about the fineness of cabbage nets. The feathers must be from time to time shaken upon the nets, and as they dry will fall through the meshes, and are to be collected for use. The admission of air will be serviceable in the drying. The whole process will be completed in about three weeks. After being prepared as above mentioned, they will only require beating, to get rid of the dust, previous to use.

Feather. A term applied by engineers to narrow ribs, placed edgewise, to strengthen framing and other parts of machines.

FEATHER-EDGED signifies any piece of work in which the edge of it is materially reduced in its thickness.

FELLING TREES. The cutting down of trees at the proper time, and in the best manner, requires both knowledge and skill. Its proper season is determined by various causes, as maturity of growth, defects in the trees, and new arrangements. Every tree that indicates decay, ought to be immediately felled, as its value will rapidly decrease. In all trees, there are three stages—youth, manhood, and age. The beginning of manhood is the fittest period for removing trees. All plantations, when arrived at maturity, ought to be cut down and replanted. Winter is the proper season for felling trees that are not to be disbarked; but summer is preferable for those of the resinous tribes. In spring and autumn, the wood is fullest of sap; in winter and summer the least so, and therefore it is the fittest time, generally speaking, for levelling them. But in felling oaks, and such as have to be disbarked or peeled, the early part of the spring, before the leaves appear, is found to be the fittest period, as the bark will at that time easily separate, or "run," as the workmen term it. The preparatory operation to felling, is disbranching the trees of such limbs as may endanger the tree in its fall. In arms of timber that are very great, it is always necessary to chop or sink in them close to the bole, and then meeting it with downright strokes, it will be severed from the tree without splitting. In felling the tree, take care always to cut it as close to the ground as possible, unless it is intended to be grubbed up; and the doing that is of advantage both to the timber and the wood; for timber is never so much valued, if it be known to grow out of old stocks. In the clearing of woodland, the extirpation of the stumps and roots is the most laborious part of the process. In British America, the ordinary method is to allow the stumps to remain for a number of years, according to their size. During this period, the smaller fibres gradually decay, and the root itself is each year removed a little from its original position by the frost. When the farmer judges that time has so far produced decay, as to render the removal of the stumps and roots practicable by the usual means, he pitches upon the spring of the year, when the soil has been loosened by the returning heat; and with the assistance of four or five men, and a couple of pairs of oxen, he effects his purpose, by a great deal of labour, and under a disadvantageous application of power, owing to the softness of the ground.



In 1821, J. Mackay, Esq. of Pictou, Nova Scotia, cut down the trees and removed the timber from a field of ten acres. The following were the means adopted by that gentleman for clearing the ground of the stumps and roots, which proved so effectual, that with the assistance of four men he cleared upon an average 80 stumps a day, and with them every root which could impede the progress of the plough. A ship's winch, or movable crane, was the machine used for accumulating a great mechanical power; this was brought into

the middle of about an acre of stumps, and fastened to the largest of them. From the barrel of the winch a chain proceeded, which extended to the farthest stump in the piece; a number of shorter chains were also provided, each having a ring at one end, and a hook at the other. By passing the hook through the ring, they were fixed upon the stumps nearest to that to which the chain of the winch was attached, and when it was raised, these chains were in succession hooked to the leader, so that the winch was employed without interruption, till the nearest stump was extracted. In clearing Mr. Mackay's field, five hands were employed; two at the winch, two in fixing the chains, and one at the stump to be raised. When the stump was large, those who attended the chains occasionally assisted in turning the winch.

Reference to the Engraving on the preceding page.—*a a* the two winch handles of the crane *b b*, which is chained to the largest stump *c; d d* the leading chain, proceeding from the barrel to a distant stump *h*, to be hooked on to the leading chain *d d* as soon as it has raised the stump *e*, and has been disengaged from it, so that the different stumps are raised in succession, from the farthest to the nearest. The winch is then removed to face the next portion, and the chain extended to the farthest it can reach, while the shorter chains are attached to the right and left stumps, and hooked on in succession to the leading chain, and thus continued until a whole circle round the winch has been cleared. Should the stump to which the winch is attached be liable to give way, it will be requisite to lash it to one or two in the rear, to secure the purchase.

FELLOES, the curved pieces of wood, usually six or eight in number, which, when united end to end, form the circular rim, or periphery of carriage wheels, and into which the spokes are inserted. See WHEELS.

FELTING. The process by which hair, wool, or silk, is worked into a fabric of firm texture, called felt, without spinning or weaving; it is chiefly employed in the manufacture of hats, and under that head will be found details of the process.

FERMENTATION. When vegetables and animals are deprived of life, the elements of which they are composed exert an action on each other; some of them enter into new combinations, others become entirely undecompounded, and the identity of the original substance is destroyed. Fermentation is of three kinds: first, the vinous; second, the acetous; third, the putrid. The two first kinds are peculiar to vegetable substances; the last is common both to vegetable and animal substances, though the change it indicates is, in reference to animal substances, more usually called putrefaction. Moisture, and generally access of air, are necessary to fermentation; and a warm temperature materially promotes it, while by an excess either of heat or cold it is entirely checked.

Vinous Fermentation.—The vinous fermentation never takes place except in substances containing sugar, and it is most remarkable in those which contain the most of the saccharine principle. If a decoction of a vegetable holding much sugar in solution, or saccharine vegetable juices, or simply a mixture of sugar and water, be exposed to a heat of 70° in a vessel either uncovered, or not entirely closed, in a short time the fluid becomes very turbid, bubbles rise to the surface and break; mucilage is at the same time disengaged, part of which sinks to the bottom, and the remainder rises to the top, where, with the bubbles entangled in it, a stratum is formed, called *yeast*. When the quantity of the fermented fluid is considerable, the operation goes on briskly for several days, afterwards it becomes gradually more languid, but it is a considerable time before it completely ceases. A fluid which has undergone the vinous fermentation is entirely changed in its properties; its specific gravity is diminished; its sweet taste and viscidity is gone; it becomes brisk and transparent, and has acquired a pungent spirituous flavour. It forms beer, cyder, wine, &c. according to the substance which has furnished the saccharine juice; and from whatever it has been prepared, it affords, by distillation, a light inflammable fluid, called *alcohol*. From the experiments of Lavoisier, it appears that sugar is converted into alcohol by the loss of a part of its oxygen. The oxygen separated is

employed to form carbonic acid gas, which produces the bubbles observed on the fermenting liquor. A small quantity of yeast is always added to liquors intended to be fermented, as it materially accelerates and renders uniform this process through the whole mass of fluid.

Acetous Fermentation. When liquors are fermented for the use of the table, they are put into casks while the fermentation is yet active; at first the bung-hole is left open, and as yeast is discharged, the barrel is filled up with a part of the fluid or wort reserved for that purpose; afterwards the vessel is closed. But if the fluid be allowed to remain a sufficient time in open vessels, the acetous fermentation comes on, which changes its taste and smell, and converts the fluid into *vinegar*. This change takes place most rapidly at the temperature of about 90°, and is promoted by changing the surfaces of the liquor by stirring it, or pouring it from one vessel to another. During the acetous fermentation the alcohol imbibes oxygen to a degree that converts it into an acid; and if the liquor which has undergone this process be distilled, pure vinegar, instead of ardent spirit, comes over. Simple mucilage will pass to the acetous fermentation, without being preceded by the vinous, or at least the vinous fermentation is so transient as not to be discernible. Wines deprived of mucilage cannot be converted into vinegar.

Putrid Fermentation. When dead vegetables contain much saccharine matter, and the other circumstances necessary to fermentation are combined, the vinous, the acetous, and the putrid fermentation, succeed each other in regular order. When mucilage is the predominant principle of the vegetable, the acetous fermentation, above described, is the first change discoverable, the putrid follows of course, as it is always the last, but the vinous does not appear. When albumen and gluten are predominant in the vegetable matter, the putrid fermentation only is apparent. We have observed the progress of a saccharine fluid, from the vinous to the acetous fermentation; let us now trace it to the putrid. When vinegar has been completely formed, and the warmth and exposure to the air in which it was formed are still continued, it gradually becomes viscid and turbid, an offensive gas is emitted, ammonia flies off, an earthy sediment is deposited, and the remaining fluid scarcely differs from water. Such is the change produced by putrefactive fermentation in a saccharine fluid. When moist vegetables are heaped together in considerable quantities, their putrefaction is attended with the production of considerable heat, their whole texture becomes less coherent, their colour dark, and nitrogen, hydrogen, carbonic acid, and ammoniacal gases, begin to be evolved. When the putrefactive process has advanced to this stage, the vegetable matter affords excellent manure; for it is obvious that the principles of vegetables are liberated, and are ready to nourish the seed or the root to which the manure is applied, while the warmth with which the decomposition is attended enables the seed or root more readily to receive the food thus offered. The putrefaction of animal substances goes on under the same circumstances that promote the putrefaction of vegetables—humidity, a temperature neither hot nor cold, and the access of the atmosphere; but is distinguished by a far greater noisomeness. The presence of the air is the least essential particular, for putrefaction goes on in vacuo, the air required being supplied by the decomposition of water. A very small quantity of salt hastens putrefaction, while a considerable quantity remarkably retards it, and is therefore used in the preservation of animal food. The first indication of putrefaction in animal substances is a cadaverous odour, their substance becomes soft, pale, then green, blue, and lastly, a blackish brown; the smell at the same time becomes more nauseous and penetrating, ammoniacal gas is perceived, other gases also escape, which are of an infectious and poisonous nature; in the end, the substance loses all traces of organization, becomes dry, soft, and reduced to a state resembling that of an earth. The worms and insects generally found among putrefying substances are not produced by putrefaction, and therefore not a necessary consequence of it; life never springs but from life, and the maggots are there because the insects from which they spring, directed by instinct, have deposited their eggs among matter suitable for their food.

FERRETTO. A substance used in colouring glass, obtained by the calcination of copper and powdered brimstone, or of copper and white vitriol.

FESTOON, in Architecture, an ornament in the form of a garland of flowers. The term is also applied to drapery, when suspended so as to form elliptic curves, with the extremities of the cloth depending.

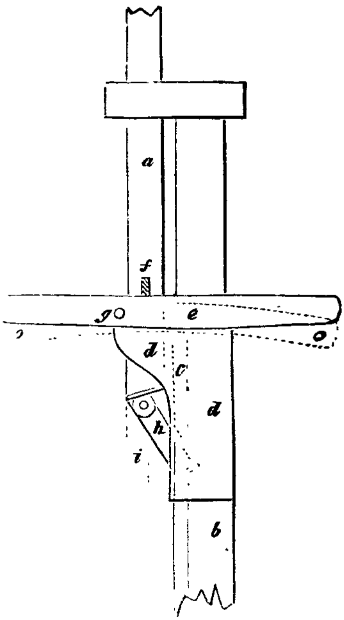
FIBRE (VEGETABLE). A substance of great use in the arts and manufactures, furnishing thread, cordage, &c. For these purposes the filamentous parts of hemp and flax are employed amongst us; in Sweden, a strong cloth is said to have been prepared from the stalks of hops; and in India, exceedingly serviceable cordage and cables are manufactured from the husks of cocoa nut.

FIBRIN. A peculiar organic compound, found both in animals and vegetables, but procured however, in its most characteristic state, from animal matter. To obtain it, we may beat blood as it issues from the veins with a bundle of twigs. Fibrin soon attaches itself to each stem, under the form of long reddish filaments, which become white by washing them. It is solid, white, insipid, without smell, insoluble in water, softens in the air, becoming viscid, brown, and semi-transparent. Fibrin does not putrefy speedily when kept under water. It shrinks on exposure to a considerable heat, and emits the smell of burning horn.

FID. A short and thick bar of wood or iron, which, passing through a hole cut in the lower part of the topmast or top-gallant mast, and resting upon the trestle trees, serves to support those masts. A most important improvement upon this part of a ship's apparatus, is the patent lever fids, invented by Mr. Rotch, by means of which ships may strike their topmasts, or top-gallant masts, at any moment, in less than one minute, and fid them again in less than five minutes. The lever fids consist of two powerful levers of the first class, resting upon iron plates or carriages, bolted upon the upper surface of the trestle-trees, and carrying the gudgeons or trunnions which form the fulcrums of the levers; these gudgeons pass through circular notches cut in the upper side of the levers, and that part of the levers which rests upon the plate being formed into the arc of a circle, of which the gudgeons are the centre, the whole weight of the masts is supported upon the carriages, instead of upon the fulcrum, which merely serves as a centre of motion. The operation of fidding a mast is as follows:—The mast being swayed high enough for the short arms of the levers to enter the fid-hole (which is defended by a very stout iron plate), the longer arms are depressed by tackles hooked to their extremities until they attain a horizontal position, when they are secured by lashings. To strike a mast (the top rope being rove and made fast below), all that is necessary is to slack the lashings until the strain is brought upon the top rope, and then to lower away. These patent lever fids may be applied to any ship without any alteration in her tops, mast, or fid-holes; and from the rapidity and certainty of their operations, are calculated to render most important service to navigators in the most trying situations, where despatch in striking a mast may be of essential consequence, as in the case of a sharp ship grounding upon a rapidly falling tide, in gales of wind at sea in a dark night. In the case of springing a topmast just above the cap, when in chase, the lever fids will be found invaluable, as the topmast may be instantly lowered until the part which is sprung is below the cap, by just shaking the vessel in the wind for half a minute, when all will be safe, and she may be kept on her course again. So sensible were the Lords of the Admiralty of the utility of this invention, that they paid to Mr. Rotch a large sum for the use of it in the Royal Navy.

Mr. Rotch has subsequently taken out a patent for a prop for supporting masts, by which the strain is transferred from the trestle trees to the lower mast, just beneath the top, and acts in a direction nearly vertical. The cut on the following page represents an outline sketch of the apparatus. *a* is the topmast; *b* the lower mast; *c* the fish (which is a strong piece of timber fixed to the lower mast to strengthen it) shown in dotted lines; *d* the cheeks of the lower mast, on which are fixed the trestle-trees *e*; *f* the fid of the topmast; *g* a bolt stay to the top-mast; *h*, *the new patent prop*, bolted to the heel

of the top-mast by means of an iron plate, connected with the hinge joint upon which it turns, the other end resting in an angular cavity made to receive it in the fish of the lower mast; *i* shows the position which the *prop* takes when the top-mast is being raised or lowered; the curved dotted lines *o o* represent the form into which the trestle-trees ordinarily become bent by the action of the top-mast. This latter effect is owing to the trestle-trees having to support the whole weight of the top-mast, with its ends resting upon the trestle-trees. To the weight is to be added the force of the wind, which has a tendency to increase that effect in a tenfold degree, especially when the inclined position in which the masts of most ships are placed is taken into consideration. If instead of the fid and the trestle-trees having to withstand all this force, the little prop *h* be put into the cavity of the fish, it will be seen that nearly the whole of it is thereby thrown diagonally upon the lower mast, which is well able to sustain it.



FILAMENT. Those extremely delicate threads of animal or vegetable production, such as are produced by the silk-worm, spiders, flax, nettles, &c.; by the combination and twisting of which, threads, cordage and cloth are made.

FILE. A steel instrument employed for shaping or giving a smooth surface to articles made of metal, bone, wood, &c. The varieties of files are very extensive, being expressly adapted to numerous different trades or branches of manufacture. There is, however, an immense variety of files which are applicable to general purposes; these are distinguished by the terms of flat, half-round, three-square, four-square, round, hand, pillar, cant, and other technical names, which denote their transverse sectional shape; then each of these shapes may be single or double cut; that is, the notches or incisions made upon them may consist of only one series of parallel lines, technically called floats, or of two series, in which the lines or incisions cross each other diagonally. Then again, either of these latter may be of different degrees of coarseness or fineness, denominated in the trade, rough, bastard, second-cut, and smooth; the latter term indicating teeth so fine and close as to produce upon metal a surface nearly smooth, and requiring only the aid of the burnisher to polish it. It is then to be understood, that each of these classes and varieties, or most of them, are made of lengths differing from two or three inches, up to twenty inches long. Even these are not all; there are also a numerous class of rasps, which have jagged teeth, and are chiefly used in working bone and hard woods; also rubbers, which are great, heavy square files, used by smiths and others; and a peculiar class of heavy files, chiefly used by millwrights and engineers, forming a medium between rubbers and files of ordinary thickness; besides a great variety of extremely delicate files of the best steel, used by watchmakers and others. When, therefore, it is considered that the file manufacture thus embraces several thousand distinctions, and that many thousands of families are constantly employed in their fabrication in the neighbourhood of Sheffield, Birmingham, and other places, an idea of the extent and importance of it may be formed. The steel employed for files is required to be very hard, and, in consequence, undergoes a longer process in the conversion, and is said to be double converted. The very heavy files are made of the inferior marks of blistered

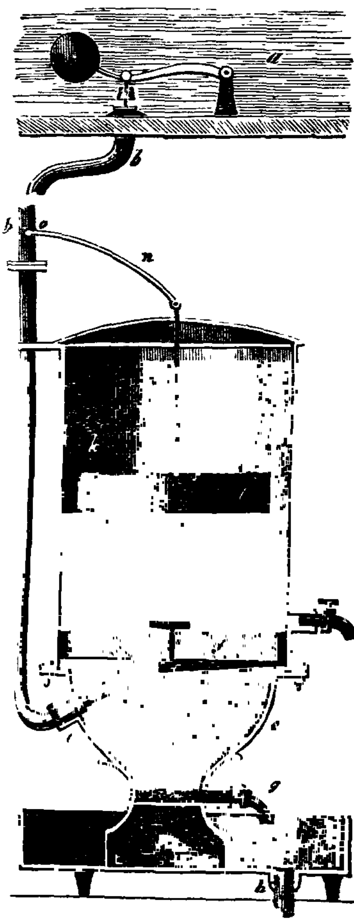
steel; those for sharpening the teeth of saws, and the more delicate kinds, are made of cast steel. The steel is previously drawn at the tilt hammer into rods of a suitable size. The flat and the square files are made wholly with the hammer and the plain anvil. Two workmen, one called the maker the other the striker, are required in the forging of heavy files, the smaller being forged by one person only. The anvil is provided with a groove for the reception of bosses or dies, which are used for the purpose of forging the half-round and three-angled files. The half-round boss contains a hollow, which is the segment of a sphere, less than half a circle. That used for the three-angled files has a hollow consisting of two sides, terminating in an angle at the bottom. In forging the half-round file, the steel is drawn out, as if intended to make a flat file, it is then laid in the die and hammered till the underside becomes round. The steel for the triangular files are tilted into square rods. The part to form the file is first drawn out with the hammer, as if intended to form a square file; it is then placed in the die with one of the angles downwards, and by striking upon the opposite angle, two sides of the square are formed into one, and consequently a three-sided figure produced, which is perfected by successively presenting the three sides to the action of the hammer. In forming the tangs of most files, it is necessary to make the shoulders perfectly square and sharp. This is performed by cutting into the file a little on both sides with a chisel, and afterwards drawing out the part so marked off to form the tang. After forging, and previous to being ground and cut, the files require to be annealed. This process is generally performed by piling up a great quantity together in a furnace for the purpose, and heating them red hot, suffering them afterwards to cool slowly. This method of annealing files, and indeed any other articles in which great hardness is requisite, is very objectionable, since the surface of steel, when heated red hot in the open air, is so liable to oxidation. A superior method of annealing is practised by some file-makers; and since hardness in a file is so essential a property, the process ought to be generally adopted. This method consists in placing the files in an oven or trough, having a close cover, and filling up the interstices with sand. The fire is made to play on every side of the vessel, as gradually and as uniformly as possible, till the whole mass becomes red hot. The fire is then discontinued, and the whole suffered to cool before the cover is removed from the trough. Steel annealed in this way is perfectly free from that scaly surface acquired in the open air; and if each corticle be perfectly surrounded with the sand, and the cover not removed before the steel is cold, the surface will appear of a silvery white colour. If the steel be suspected to be too kind, from containing too little carbon, powdered charcoal may be employed instead of sand, or sand mixed with charcoal. In this case the files should be stratified alternately with the charcoal, in order that the extra conversion may be uniform. The next thing is to prepare the files for cutting, by making the surface to contain the teeth as level as possible. This was formerly effected by files, and the process is called striping. The same is still practised by the Lancashire file-makers (who excel in the manufacture), and by others not having the convenience for grinding. The greatest quantity of files are, however, *ground*, to prepare them for cutting. The stones employed for this purpose at Sheffield are of a compact and sharp texture, of great diameter, and about eight inches broad over the face. When used, the surface is kept immersed in water; the grinder sits in such a position as to lean over the stone, whilst its motion is directed from him. The next process is that of cutting the files, which is performed by means of a chisel and hammer on an anvil. The chisel and hammer are of such a size as the size and cut of the file require. The file-cutter is also provided with a leather strap, which goes over each end of the file, and passes round his feet, which are introduced into the strap on each side, in the same manner as stirrups are used. He therefore sits as if he were on horseback, holding his chisel with one hand, and his hammer in the other, at the same time he secures the file in its place by the pressure of his feet in the stirrups. While the point of the file is cutting, the strap passes over one part of the file only, while the point rests upon the anvil, and the tang upon a prop on the other side of the strap.

When one side of the file is single cut, a fine file is run slightly over the teeth to take away the roughness, when they are to be double cut; and another set are then cut, crossing the former nearly at right angles. The file is now finished on one side, and it is evident that the cut side cannot be laid upon the bare anvil to cut the other. A flat piece of an alloy of lead and tin is therefore interposed between the serrated surface and the anvil, while the other side is cut, which completely preserves the side previously cut. Rasps are cut in precisely the same way, using a triangular punch instead of a flat chisel. The art in cutting a rasp is to place every new tooth opposite to a vacant space in the adjoining row of teeth The last and most important part of file-making is the hardening them. In effecting this, three things are to be observed: 1st. To prepare the file on the surface, so as to prevent it from being oxidated by the atmosphere when the file is red hot, which effect would not only take off the sharpness of the tooth, but render the whole surface so rough that the file would, in a little time, become clogged with the substance it had to work upon. This is accomplished by laying a substance on the surface consisting of salt dissolved in water, and stiffened with ale grounds or common flour. When it fuses, this forms a kind of varnish, which defends the metal from the action of the air. 2d. The heat ought to be very uniformly red throughout, and the water in which it is quenched fresh and cold, for the purpose of giving it the proper degree of hardness. And lastly, the manner of immersion is of great importance to prevent the files from warping, which, in long thin files, is very difficult. After the file is properly heated for the purpose of hardening, it should be cooled as soon as possible. The most common method of effecting this is by quenching it in the coldest water. All files, except the half-round, should be immersed perpendicularly, as slowly as possible, so that the upper part shall not cool. This management prevents the file from warping. The half-round file must be quenched in the same steady manner, but at the same time that it is kept perpendicular to the surface of the water, it must be moved a little horizontally in the direction of the round side, otherwise it will become crooked backwards. When the files are hardened, they are brushed with water and coke dust, the surface becoming of a whitish grey colour, as perfectly free from oxidation as before it was heated. They may likewise be dipped in limewater, and dried before the fire as rapidly as possible; after which they should be rubbed over with olive oil, in which is mixed a little turpentine, and then they are finished. To preserve them for use, or pack them for sale, they are wrapped in stout oiled brown paper in half-dozens, the paper interposed between each preventing any injury to the opposed teeth.

The operation of simple file cutting seems to be of such easy performance, that it has for almost two centuries been a sort of desideratum to construct a machine to perform that which is not only done with great facility by the hand, but with wonderful expedition. It is said, that a lad not very experienced in the business, will produce with his hammer and chisel nearly three hundred teeth in a minute. With respect to machinery, Mathurin Jousse, in a work entitled, *La Fidelle Ouverture de l'Art de Serrurier,* published at La Flesche, in Anjou, in 1627, gives a drawing and description of one in which the file is drawn along by shifts by means of wheel-work, and the blow is given by a hammer. There are several machines for this purpose in the *Machines approuvées par l'Academie Royale de Paris.* There is also one published in the second volume of the *Transactions of the American Philosophical Society;* and a patent was taken out by Mr. William Nicholson, in 1802, for the same object. From the knowledge, talent, and assiduity, of the last-mentioned inventor, we may be assured that it was a very elaborate and judiciously-constructed machine; nevertheless it was found wanting, and never got into practical operation; files, therefore, continue to be cut as they were a century ago. File-cutting is an art that appears, at first thought, extremely simple, but a little investigation of the subject will convince the reader, (as it did ourselves many years ago, when we designed a machine for the purpose,) that it abounds with difficulties, which, though probably not of an insuperable nature, are such as call for unremitting study, the devotion of much time, and the incurring of

a considerable expense to accomplish. No man, therefore, should undertake it who is not possessed of abundant capital, leisure, and constructive skill. In the operations of filing, the coarser cut files are always to be succeeded by the finer, and the general rule is to lean heavy on the file in thrusting it forward, because the teeth of the file are made to cut forwards; but in drawing the file back again to make a second stroke, it is to be lifted just above the work, to prevent its cutting or rubbing as it comes back. The *rough* file, or a rubber, serves to take off the most uneven part of the work; then follows the *bastard* file, to reduce the file cuts or scores of the rough file, and next usually a *smooth* file, to remove the scores of the bastard, and prepare the work for the burnisher, if it is to be polished.

FILLAGREE WORK. A kind of enrichment on gold or silver, wrought delicately in manner of little threads or grains, or both intermixed. In Sumatra, manufactures of this kind are carried on to very great perfection. But what renders this a matter of great curiosity is, that the tools made use of are very coarse and clumsy. The gold is melted in a crucible of their own forming, and instead of bellows, they blow with their mouths through a piece of bamboo. They draw and flatten the wire in a manner similar to that of Europeans. It is then twisted, and thus a flower, or the shape of a flower, is formed. Patterns of them or of foliage are first prepared on paper, of the size of the gold plate on which the filagree is to be laid. According to this, they begin to dispose on the plate the larger compartments of the foliage, for which they use plain flat wire of a larger size, and fill them up with their leaves. A gelatinous substance is used to fix the work, and after the leaves have been placed in order, and stuck on bit by bit, a solder is prepared of gold filings and borax, moistened with water, which they strew over the plate, and then putting it on the fire a short time, the whole becomes united. When the filagree is finished, it is cleaned with a solution of salt and alum in water. The Chinese make most of their filagree of silver, which looks very elegant, but is deficient in the extraordinary delicacy of Malay work.



FILLET, in Architecture, is a narrow rectangular moulding. In the metallic framing of machinery, narrow moulded slips or fillets are put in the angles, to facilitate the casting and strengthen the structure.

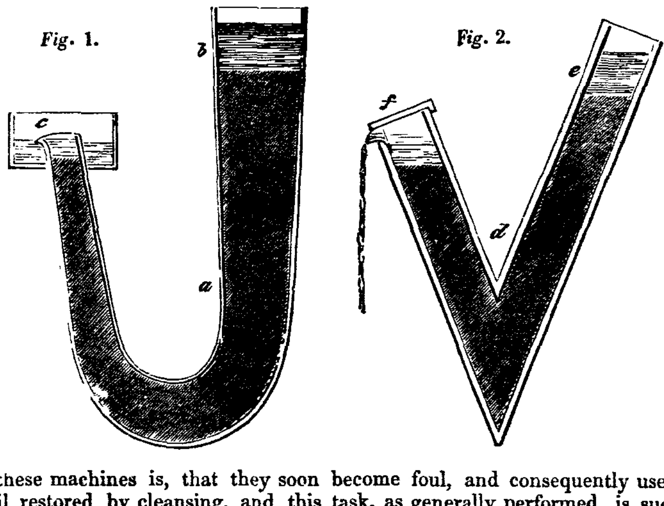
FILTRATION. A process for freeing liquids from particles held in suspension in them, by causing them to percolate through various porous substances, which intercept the insoluble matter, but allow a passage to the liquids, which are thereby rendered clear and transparent. The purpose to which filtration is most extensively applied, is the purification of water for domestic purposes; and from the importance of pure water as regards the preservation of health, and from the general complaints of the impurities

abounding in the water supplied by the different companies, the subject has of late excited much attention, and a variety of filtering apparatus have been offered to the public, some few of which we propose to describe.

The first of these machines which we shall notice is Messrs. White and Aveline's "artificial spring," in which the water is made to filtrate upwards by its pressure against the under side of a stone, the quantity filtered depending upon the area of the stone, and the height of the reservoir from which the water descends; but with a head of 35 feet, which can be obtained in most houses in London, a stone of 10 inches square will filter nearly thirty gallons per hour. The engraving on the opposite page exhibits a vertical section of the apparatus. *a* is the cistern which receives the water in its impure state; it has a ball float and lever to keep a constant head of water over the pipe *b*, and likewise to prevent any air passing down it. The pipe *b b* is shown broken off, that the space between may be considered as of any required length. To the lower end of the pipe there is a nozle *c* through which the pipe passes, which causes the water to shoot up against the under surface of the filtering stone *f*. Through this stone the water oozes with great rapidity, leaving the animalculæ and other impurities in the lower part or basin *e* of the machine, from whence they are drawn off occasionally by the cock *g*, and carried away by the waste pipe *h*. When the filtered water rises in the reservoir above *k* to a certain height, the filtration is stopped by the rising of the float *l*, which by its lever or rod *n*, shuts a cock *o* in the supply pipe. When the stone has become charged with a deposit on its under surface, it is capable of being cleansed by the scraper *s* which is turned round by means of a handle shown at the bottom of the reservoir *k*, the axis passing through the stone; provision is thus made for reviving the filtering properties of the stone whenever required, and with very little trouble.

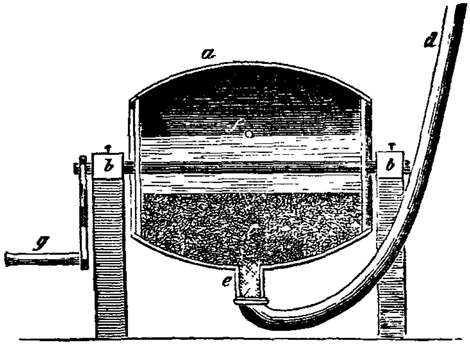
A very old contrivance for filtering water, but which has been the origin of most of the more recent apparatus for the purpose, consists in nearly filling the two legs of a pipe, formed either of metal as in *Fig.* 1, or of wood as in *Fig.* 2, with washed sand, leaving merely a space at *b* and *e* to receive the turbid water, and another at *c* or *f* for the filtered water to run off by. The chief objection

Fig. 1. *Fig.* 2.



to these machines is, that they soon become foul, and consequently useless, until restored by cleansing, and this task, as generally performed, is such a laborious, tedious, and slopping one, that these filters are usually abandoned in a short time. This objection seems to be obviated in the arrangement shown in the cut on the following page. *a* is a barrel capable of being turned round, but rendered stationary by pins passing through the extremities of their bearings at *b b*; *c* is a bed of sand occupying about one-third of the cask; *d*

is the supply pipe or hose, (any flexible tube,) which conducts the turbid water from a reservoir above, into the cask; at *e* is a union joint and nozle piece, containing a sponge, which serves three purposes: it prevents the grossest impurities of the water from entering among the sand; it prevents the column of water from forcing up the bed of sand; and it prevents the sand from falling into the pipe. The filtered water is drawn off at *f*. When the sand requires cleaning, the pins at the bearings of the axis are taken out, and the winch turned so as to bring the union joint to the top of the cask, previous to which the pipe should be detached by unscrewing. The sponge being now removed, the water may be let on freely at top, and the barrel turned by the winch *g*, by which means the sand is expeditiously washed, the water being let on and run off as often as necessary, which it is obvious may be effected with so much facility, that the filtering powers may be at any time renewed in a few minutes.



The following engraving, *Fig.* 1, represents an apparatus of a convenient form, by Mr. James, of Knightsbridge. It consists of two vessels (A and B,) of stone ware, placed upon a strong stand *c*. The upper vessel, which is covered, receives the impure water in a chamber *d*, at the lower part of which there is a large aperture, stopped by a sponge *e*, which detains the grosser impurities: hence the water passes through a finely perforated earthenware plate into a layer of six inches of prepared charcoal, through which the water filters, and is

Fig. 1.

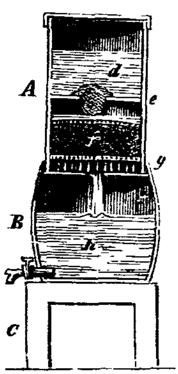
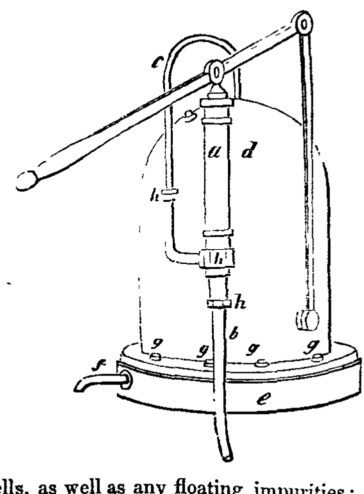


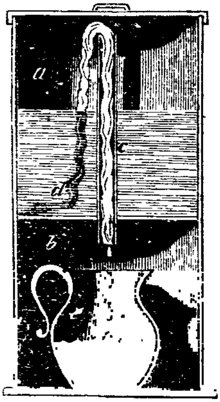
Fig. 2.



thereby purified from any noxious smells, as well as any floating impurities; it then passes through another perforated plate *g*, and is received at *h* into the separate vessel, which is a stone ware cask, from which it may be drawn off at pleasure by the cock.

A very convenient filtering machine, from its portability, is Wiss's patent filter, which is shown in the preceding cut, *Fig.* 2. *a* is a force pump; *b* a

suction pipe, to be inserted in a pail or other vessel of water; *c* the pipe which conducts the water out of the pump to the top of the vessel *d*; *e* is a receiver for the purified water; *f* a cock for drawing it off; *g g g*, screws for separating the receiver from the machine when required. The filtering substances used in this apparatus are of the same description as in the foregoing ones. The upper portion of the filter down to the letter *d* in the engraving, is left vacant for the dirty water which first passes through a thin bed of charcoal, and then through a bed of sand occupying the remainder of the vessel, and supported by a perforated metal plate, covered with a few layers of flannel.



A very simple method of freeing water from its impurities by means of the capillary attraction of fibrous substances is represented in the annexed engraving. *a* is the reservoir, *b* the lower compartment, *c* an open tube soldered into the bottom of the reservoir, in which is put a wick of cotton or wool, (the latter is best,) with one end immersed in the bottom of the reservoir, whilst the other end hangs down a little below it, forming a kind of syphon. The water in rising by the capillary attraction between the filaments deposits the gross matter floating therein, and descends in a comparatively pure state into the vessel *b*, or into a jug placed therein.

The figures represented in page 502, are a portion of Mr. Suwerkrop's apparatus for filtering and heating water. *Fig.* 1 shows a side elevation of the vessels in question; and *Fig.* 2 is a vertical section of the same. The letters have reference to similar parts in each figure. The water is supposed to be conveyed by the pipe *a* from a reservoir situated upon a higher level than the cask *b*, which is divided by the partition *c* into two equal parts, forming thereby a double filtering machine. In each of these divisions, the filtering substances and the arrangement of them are the same. As the water flows from a higher level, it will of course ascend through the filtering substances, and flow out at the upper part. The first substance which it has to pass through is a circular mat *d*, made by coiling up and sewing together a rope of platted horse-hair, which detains the grossest of the impurities; from this it passes through a floor or false bottom of wood, *e*, pierced throughout with numerous small holes; upon the wooden bottom is laid first a stratum of coarse gravel or small pebbles, over this is put a layer of finer, then a layer of finer still, and lastly, a bed of sand *f*, about six or seven inches thick; from this the water rises in a tolerably pure state; if not sufficiently purified, instead of drawing it off for use, it may be allowed to pass through the curved pipe *h* into the upper division *i* of the cask. The water continuing to rise, then percolates successively through the horse-hair mat *j*, the perforated floor *k*, and the various strata of the sand and gravel *l*, finally flowing out of the cask, and through the pipe *m*, into the heating vat *n*. The vat is constructed with a furnace *o*, and flue *p p* inside of it, all made of copper, except the grating for the fuel, which is made of cast iron as usual; copper being preferred for the flue on account of its oxidating less rapidly than iron or other cheap materials. The heated air or gases first rise up the neck *q* into the hollow sphere *r*, which becomes soon occupied with intensely heated air, from whence it has little disposition to descend and escape by means of the spiral tubes, which finally become flues for the grosser products of the combustion; as these tubes, however, make a long circuitous course through the tub of water, the heat is almost wholly absorbed by it. The furnace and flues are supported and kept in their positions by stays fixed to the sides of the vat, as shown. The three closed apertures in the cask *b*, *Fig.* 1, are for the several purposes of washing the bottoms of the horse-hair mats, by passing water through them downwards; and for taking out and refreshing the layers of sand and gravel when they have become foul by deposition from the water.

Fig. 1.

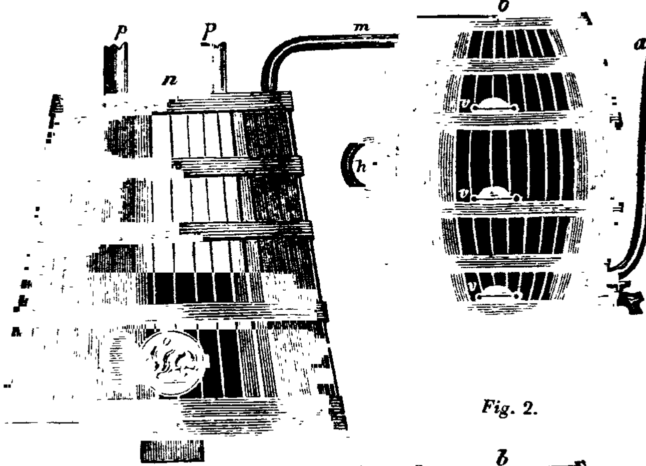
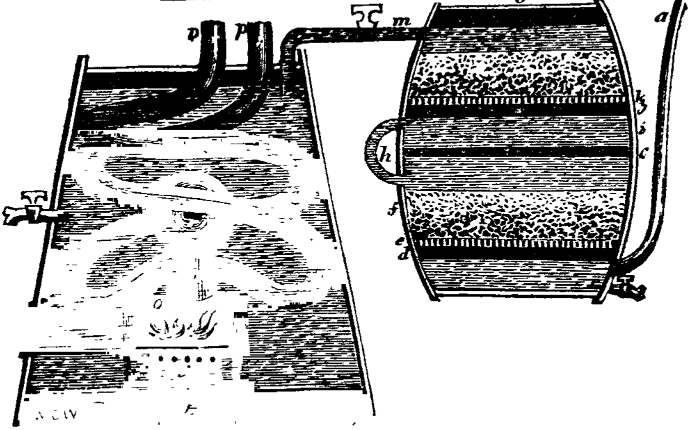
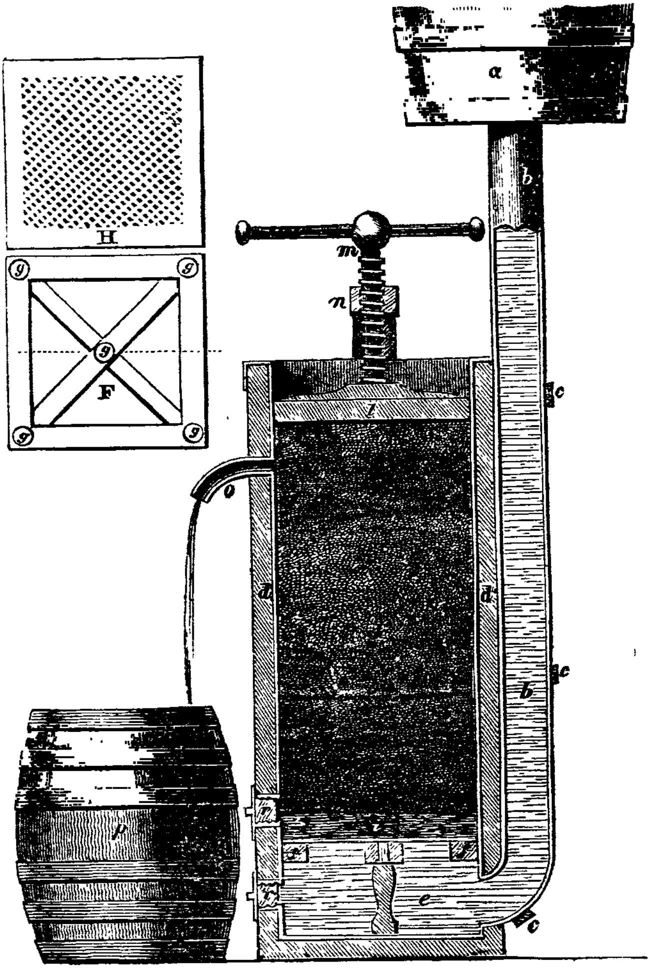


Fig. 2.



The engraving on the next page represents an apparatus contrived by Messrs. Williams and Doyle, for the purpose of separating the salt from sea-water, by merely causing it to percolate through a body of sand under mechanical compression, and thus to render it fresh. Could this object be obtained by such means, the invention would doubtless be one of the utmost importance to navigation, as it would render a store of fresh water unnecessary, thereby affording additional stowage for provisions or cargo; but we are not aware of any experiments proving that substances dissolved, and chemically combined with a liquid, can be separated by filtration; we therefore apprehend that the apparatus would be ineffectual for the object the inventors had in view, although it may prove very efficient in freeing water from any impurities floating or suspended in it. The following description of the engraving (which represents one of the several modes of construction proposed by the inventors), is derived from the specification of their patent. *a* is a part of the cask supposed to contain sea water; *b* a tube descending therefrom, made fast by bands *c c c* to the filtering apparatus *d d*, which is a strong square trunk of wood, lined internally with sheet lead, which are cemented together to prevent the interposition of water. This part of the apparatus is given in section, that the construction and arrangement may be seen at one view; *e* is the lower chamber, where the water is

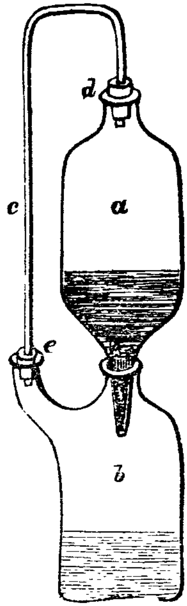
first received; *f* is a strong stool of open frame work, supported on five stout legs, *g*. A plan of this stool is given in a separate figure F, the situation of each of the five legs being marked with a *g*. Over this short frame is nailed a plate of copper, pierced with numerous small holes; this plate is also shown by a separate figure H. Over the perforated plate are several layers of woollen cloth, or woven horse-hair *i*, and above these a body of sand *k*, filling up the



entire trunk; on the top is placed a sliding cover *l*, which is operated upon by a strong screw *m*, working through a fixed nut *n*, which is supported by curved iron arms, extending from opposite sides of the trunk. The sand having been compressed, by the agency of the screw, into a more dense and compact mass, is prevented from rising by the pressure of the water, which percolating through the minute interstices to regain its level, deposits its salt, and runs out by the pipe *o* in a fresh state into a vessel *p* placed to receive it. When the sand has become saturated with salt, it is to be removed by taking out the screw and the pressing board *l*; the man holes *r r* may then be opened by unscrewing the plugs,

when the other materials may be easily sifted. These matters being completed, a fresh quantity of sand may be taken from the ballast of the ship, and the process of filtration continued as before.

We shall close this article with a description of a very convenient apparatus for filtering liquids out of contact with the atmosphere, invented by Mr. Donovan. By means of this arrangement, alkalies can be preserved in their caustic state, the absorption of carbonic acid by the alkali being prevented. *a* is a bottle of green glass, with a funnel-shaped end inserted into another bottle *b*, the junction being luted or ground to fit closely; the neck *d* of the upper vessel has a cork tightly fitted to it, perforated in the middle for the reception of the glass tube *c*, which being bent downwards, enters the branched neck *e* of the lower vessel, thus connecting them together, and opening an air passage between them. The funnel-shaped end of the upper vessel has a piece of linen, loosely rolled up, placed in it, for the purpose of filtering, but for the corrosive acids a stratum of pounded flints should be employed instead of the cloth. To charge the upper vessel with the alkaline solution, the tube *c* must of course be removed, and the first droppings should be allowed to run to waste previously to the apparatus being fitted together, that no absorption of carbonic acid may take place in the filtered liquor. When the whole is properly closed, the filtration will proceed without the possibility of absorption. Now it is evident that no liquor can fall from the upper vessel without an equal volume of air entering it, and that none can enter the lower without an equal bulk escaping from it. Both these conditions are fulfilled by the connecting tube *c*, the air being driven from the lower into the upper vessel at every dropping of the filtered liquid. The whole process is therefore conducted without the access of more air than the vessels at first contained, and in the most cleanly and perfect manner. The utility of this contrivance is very extensive. The most volatile liquids, as ether, alcohol, ammoniacal liquors, volatile oils, &c. may be filtered without loss, as the vapours cannot escape during the operation; and by the exclusion of the atmosphere in the filtration of a variety of fluids, other injurious effects to which they are subject by the common process, may be entirely obviated.



FIRE, in Natural P[illegible] the decomposition of combustible bodies, accompanied [illegible] ıe word, however, has been used in such various senses by philosophers of different schools, that in works of close reasoning it is now generally exchanged for that of combustion, as a term affording a more definite meaning. Fire, under this view of the subject, is not a substance, but a quality. It supposes two or more bodies entering into combination, attended with an emission of light and heat. All these phenomena may take place separately, but it is a compound operation, resulting from the union of the whole, that alone produces fire.

FIRE ARMS are all sorts of arms charged with powder and ball; as cannon, mortars, muskets, pistols, &c. See CANNON, GUN, &c.

FIRE ENGINE. An engine for projecting water upon buildings on fire. Buckets composed of wood, leather, or other suitable material, were the only means employed in England and on the continent for extinguishing fires, up to the middle or close of the sixteenth century. The earliest mention of any description of fire engine with which we are at present acquainted, occurs in the building accounts of the city of Augsburg, in Germany, in the year 1518. They are there described as "instruments for fires," and "water syringes, useful at fires." They are stated to have been made by Anthony Blatner, a goldsmith of Friedburg, who, in the year above mentioned, became a citizen of

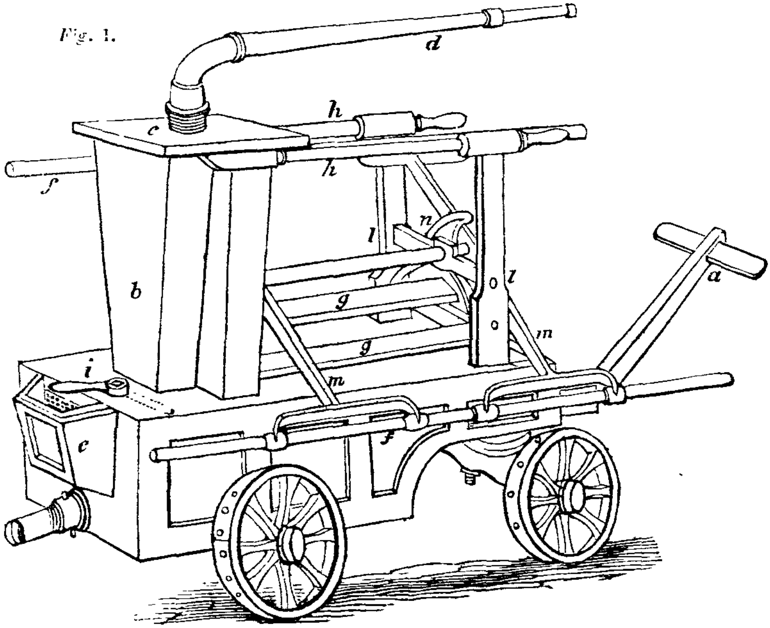
Augsburg. These syringes appear to have been of considerable magnitude, as they were mounted on wheels, and worked by levers; they are also represented to have been expensively constructed. Caspar Schott, the well-known Jesuist, states, that small engines of this description were used in his native city (Konigshofen) in the year 1617. This writer has also furnished a short account of a much larger one, which he saw tried at Nuremburg, in 1657. It was constructed by John Hautsch, of that place, and was mounted on a sledge ten feet long by four feet broad, which was drawn by two horses. It had two working cylinders placed horizontally in the cistern, which was eight feet long, four feet high, and two feet broad. It was worked by twenty-eight men, and threw a jet of water one inch in diameter to the height of eighty feet. This is the largest and most powerful squirting engine of which we have any record. The English appear to have been unacquainted with the progress made by the German engineers, or to have been very slow in availing themselves of their discoveries; for at the close of the sixteenth century, *hand-squirts* were first introduced in London for extinguishing fires. They were usually made of brass, of various sizes, holding from two to four quarts of water each. Those of the former capacity were about two feet and a half long, and one inch and a half in diameter, that of the nozle being half an inch. They were furnished with handles on each side, and every syringe required three men to work it. One man on each side grasped the handle in one hand and the nozle in the other, while a third man worked the piston or plunger, drawing it out while the nosel was immersed in a supply of water, which filled the cylinder; the bearers then elevated the nozle, when the other pushed in the plunger, the skill of the bearers being employed in directing the stream of water upon the fire. In the vestry-room of St. Dionis Backchurch, in Fenchurch-street, London, there are still preserved several of these syringes, the property of that parish. They are said to have been used at the great fire in 1666, when one of the set (originally six) was lost, and several others much damaged. These syringes present a valuable and interesting relic; for although the number of them formerly dispersed throughout the city was once very great, very few indeed of them are now to be seen. Soon after the commencement of the seventeenth century the Londoners perceived the convenience that would arise from fixing these squirts in a portable cistern, and applying their power through the medium of a lever: the fire engine thus obtained was considered a great mechanical achievement. The advantages resulting from this arrangement were certainly considerable, as they permitted a larger syringe to be used, which could be worked easier, as well as much faster, than the hand squirt. This simple form of engine, however, had many inconveniences; they projected the water by spurts only, a cessation of the stream taking place between each stroke of the piston, in consequence of which a great deal of water was lost, and a difficulty was experienced in accurately projecting the stream. To be useful, it was also necessary to place these engines very close to the fire, which exposed the persons working them to imminent danger from the falling of the burning buildings. That these engines were but imperfectly constructed, and deficient in strength, we learn from a recorded circumstance, that three of them which were taken to extinguish a large conflagration on London bridge, in 1633, and were then considered "such excellent things, that nothing that was ever devised could do so much good, yet none of these did prosper, for they were all broken." The following description of an engine of this kind has been handed down to us by Mr. Clare, in his work on the *Motion of Fluids*, published in 1735. "Engines for extinguishing fires," he observes, "are either forcing or lifting pumps, and being intended to project water with great velocity, their effect in great measure depends upon the length of their levers, and the force with which they are wrought. A common squirting engine which was constructed on the latter principle, consisted of a large circular cistern, like a great tub, mounted upon four small solid wheels, running upon axletrees, which supported the vessel. A cover or false bottom, perforated with numerous small holes, was fixed inside the cistern, about a foot below the upper edge, and about three feet from the bottom. In the centre of the perforated cover was fixed a lifting

pump, to the piston rod of which was attached a cross-tree carrying two vertical connecting rods, which were simultaneously worked up and down by manual labour, by means of two curved levers (similar to common pump handles,) on opposite sides of the machine. During the downward motion of the piston, a quantity of water passes through the valve on its upper surface, and gets above the piston, and during the ascending stroke, this water is driven with great velocity through a branch pipe provided with a flexible leather joint, or by a ball-and-socket motion, screwed on to the top of the pump barrel. Between the strokes the stream is discontinued. This engine is supplied with water poured into the cistern by buckets, &c., the perforated cover before mentioned keeping back all such matters as would be likely to choke or injure the pump-work." A year after the great fire of London, that is, in 1667, an act of Common Council was passed "for preventing and suppressing fires for the future," in which, among other salutary provisions, was enacted that the several parishes, the aldermen, and different companies, should provide a certain number of buckets, hand squirts, fire engines, &c.; which shows that these were the only contrivances then known for the purpose. We may also infer that the fire engines were not much to be relied upon at that time, from the greater importance attached to hand squirts and buckets. With such inefficient means it is not to be wondered at that fires spread as they used to do, but rather, taking into account the buildings of that period, that they were extinguished at all. Towards the close of the seventeenth century, M. Duperrier, in France, Leupold, in Germany, and Newsham, in England, introduced, almost contemporaneously, fire engines of a very improved description, which soon came into general and extensive use. The most novel and important feature of these engines consisted in the employment of an air chamber, which rendered the stream of water continuous and uniform; together with the equally important and valuable addition of the flexible leathern hose, of any requisite length, invented by the brothers Jan Van der Heide, and first tried by them at Amsterdam, in the year 1672. These contrivances enabled the stream of water to be conveyed a considerable distance from the engine, and directed upon the flames with the greatest precision and effect. In the engines of Leupold, Duperrier, and some others, one working cylinder only was employed in conjunction with an air vessel. These machines very much resembled the common garden engines of the present day, which are too well known to require describing in this place. Newsham used two cylinders; and the following description of his fire engine will be read with much interest, when it is considered that, so perfect was his machine, at the expiration of above a century we still find it nearly as he left it. Various convenient alterations and improvements have in the course of this period been made in the details of this engine, but the general character and mode of construction adopted by Newsham have not yet been surpassed.

The following engraving represents a perspective view of Newsham's engine, ready for working. It consists of a strong oak cistern, about three times as long as it is broad, mounted on four wheels, and drawn by the handle *a*. The under part of the cistern is cut away in front, to allow the fore-wheels to lock in turning round: the earliest engines were not furnished with this contrivance, but none are now built without it. At *b* is an inverted pyramidical case, enclosing the pumps and air vessel, forming a platform *c*, on which the fireman formerly stood to direct the jet of water issuing from the spout or branch pipe *d*. This branch pipe is attached to the air vessel by two brass elbows, the first of which is screwed on the top of the air vessel, and the second elbow screws upon the first by a fine screw of several threads, so truly turned as to be perfectly water-tight in every direction. The first elbow revolves on the top of the air vessel horizontally, while the second elbow revolves on the first vertically; the combination of these two motions, therefore, permits the branch pipe to be guided in every possible direction. This contrivance, however, is now obsolete, except in small garden engines, where it is used in an improved form. The flexible leather hose affords such a ready and convenient method of conducting the stream of water to any required point, that all fire engines are furnished

with a proper quantity of it, to the extremity of which the branch pipe is attached. At the hinder part of the engine is seen a strong leather suction pipe (prevented from collapsing by a spiral piece of metal running throughout its length), one end of which is screwed on, when required, to a brass nozle at

Fig. 1.



the lower end of the cistern; the other end is furnished with a rose or strainer, and immersed in the water supplied by a pond, fire-plug, &c. To the hinder part of the cistern is added a wooden trough *e*, with a copper grating (for keeping out stones, sand, dirt, &c.) through which the cistern is supplied with water, when the suction pipe cannot be used. An open space is left in the fore part of the engine, also furnished with a copper grating, through which water may be poured into the cistern. In working this engine, the handles *f f*, visible on each side, are moved up and down, which gives alternate motion to the two pumps. The working is also assisted by persons who stand on two suspended treadles *g g*, throwing their weight on each alternately as they descend, and keeping themselves steady by means of the two rails *h h*. The use of treadles, however, has been discontinued for some time, and they only now remain in a few of the oldest engines. Over the hind trough there is an iron handle or key *i*, which turns the suction cock (a three-way cock) situated beneath it. While the engine is working from water drawn through the suction pipe, the handle *i* stands in the direction of the cistern, as drawn; but when the engine works from water contained in its own cistern, this handle is turned a quarter round, into the position shown by the dotted lines. Between the pyramidal case *b* and the fore end of the engine, there is a strong square iron shaft *k*, lying in a horizontal position over the middle of the cistern, lengthwise, and playing in brasses at each end, one of which is seen placed between the two uprights *l l* supporting the hand-rails. Upon this shaft are fitted two stout iron bars or levers *m m*, one at each end, which carry the cylindrical wooden handles *f f*, by which the engine is worked. The treadles *g g* are suspended at the end by pitched chains, and receive their motion jointly with the handles that are on their respective sides, by means of iron double sectors fixed upon the shaft *k*;

the foremost sectors are seen at *n*, the others are contained within the upright box *b*.

Fig. 2, in the subjoined engravings, is a section of the working parts of this engine through the cylinders, as seen on looking from the fore part of the cistern towards the air vessel; *o o* are the working cylinders or pump-barrels; *p p* the piston rods, with square holes to carry one end of the treadles; *q* is the double sector connected with the piston rods by the chains before mentioned. It will be seen that there are two chains to each piston, one passing from the top of the sector to the lower end of the piston rod; the other from the top of the piston rod to the bottom of the sector. The chains are riveted to the sectors, and attached to the piston rods by screw nuts, which allow them to be kept constantly tight. The pistons *r r* are formed of two round plates of brass, smaller in diameter than the barrels, put into stout leather cups, and fastened together by a nut, which screws on the piston-rod below the pistons; *m m* is a portion of one of the levers, by which the engine is worked; the situation of the two entrance-valves is seen at the bottom of each cylinder. *Fig.* 3 is another section, taken vertically through the hinder part of the engine, showing one of

Fig. 2.

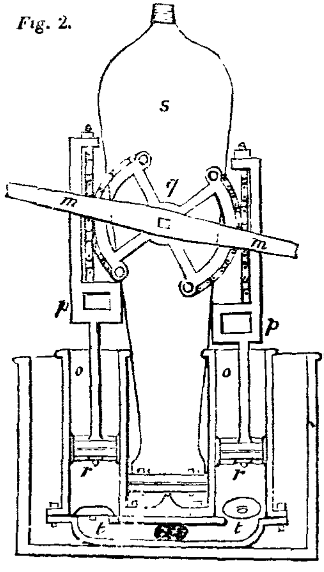
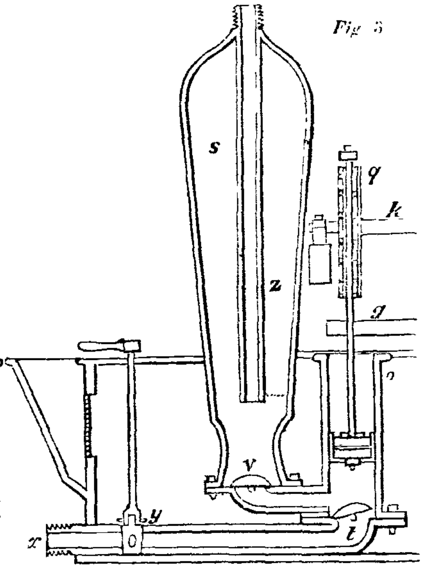


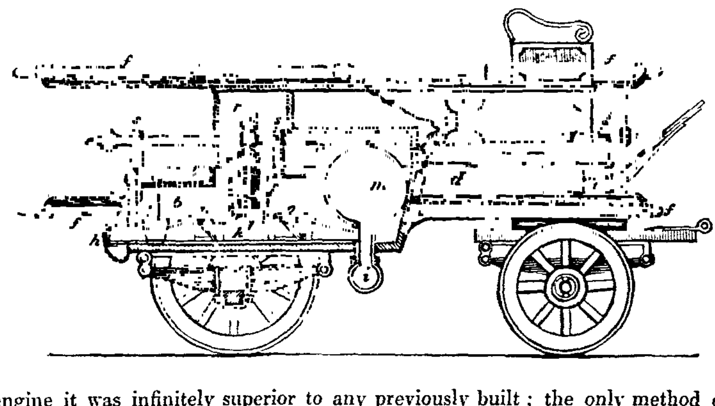
Fig. 3.



the cylinders *o* and the air vessel *s*. On the floor of the cistern is placed the standing-piece, or sole, of cast-brass, which reaches from the nozle *x* through the suction cock *y*, and afterwards divides itself into two branches, so as to open under each of the barrels; one of these passages is seen in the figure, the other is situated exactly behind it; through these channels water is conveyed to the pumps, either from the cistern itself, or from any place without, by means of the suction pipes. The two cylinders are screwed down upon the standing, or as it is frequently termed, the sucking piece, with plates of leather between them, which makes the joints water-tight, and also forms the valves, one of which appears at *t*. Each cylinder has a projecting piece cast on its lower side, which forms a seat for the air vessel, and a communication into it, which is closed by a valve opening upward at *v*. The leather valves are kept closed, and also strengthened by a piece of metal having a tail, which passes through the leather, and is cross-pinned under it. When the engine is at rest, all four of the valves continue closed by their own weight; but when the engine is working, two are opened and shut alternately. *q* is the sector on the shaft *k*,

and *g* is one of the treddles in its bearing on the piston-rod; *s* shows the internal construction of the air vessel. The action of this engine is exceedingly simple; on raising the piston *r* a partial vacuum is produced in the cylinder *o*, when the pressure of the atmosphere forces the water up the suction pipe through the cock *y*, along the sole, and lifting the valve *t* into the cylinder. Upon the piston reaching the top of its stroke, and beginning to descend, the valve *t* closes, and prevents the water, which has entered the cylinder, from returning by the way it came; being urged by the forcible descent of the piston, it is driven along the communication into the air vessel, raising the valve *v* in its progress, which closes again the moment the water has all passed through. While this process has been going on, the other cylinder has become filled with water, which is now discharged in its turn into the air vessel, and so on continuously. On the water first entering the air vessel, a quantity of air is expelled; but so soon as the water rises to the dotted line, the lower orifice of the exit pipe becomes covered, and the escape of any farther portion of air is prevented; the air is therefore gradually driven by the continued influx of water into a much smaller space than it originally occupied, and by its elastic force reacting on the surface of the water, drives up the upright pipe *z*, along the leather hose, and out at the branch-pipe, with so great velocity as to break windows, &c., and throw up a jet to the height of sixty or seventy feet. Newsham met with great encouragement, his patent being renewed for a second term; his engines were eagerly purchased by the government, nobility, and gentry, the different parishes, and by the various fire insurance companies that were formed about this time; viz. the Hand-in-Hand, in 1696; the Union, in 1714; and the London Assurance Corporation, in 1720.

In the year 1792, Mr. Charles Simpkin took out a patent for an improvement in fire-engines, which consisted in the employment of separate chambers for containing the valves, instead of placing them within the cylinders and air vessels, as was done previously. Mr. Simpkin, (afterwards of the firm of Hadley, Simpkin, and Lott,) Long Acre, London, materially altered the internal arrangement of the working parts, and constructed an engine much more compact and convenient than any of its predecessors. As a travelling



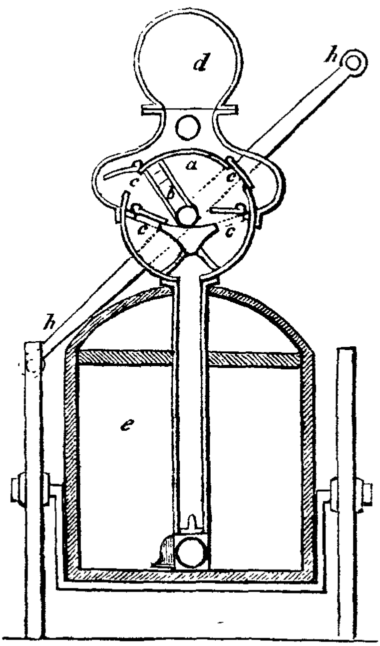
engine it was infinitely superior to any previously built; the only method of conveying Newsham's engine about, was by placing it in a cart or waggon made purposely for it, and many of our metropolitan readers will recollect that the London Assurance, Royal Exchange, and Phœnix Fire Offices, continued to run Newsham's engines in this manner to the end of the year 1832, when these and other offices combined in forming a general fire-engine establishment, which adopted Simpkin's form of engine. The above cut represents a side elevation of one of Mr. Simpkin's engines, the principal working parts of which are shown in section. The cistern *a b* is of oak, about seven feet long by two feet broad; the pockets *d* and the upper part *c* are made of fir, for the sake of lightness, great

strength not being required in these parts. The cistern is supported by strong springs on four substantial wheels. The hinder axle is bent like a crank, to give due play to the springs, and permit large wheels to be used without raising the body of the engine to an inconvenient height for working. The fore carriage locks under the front of the cistern, which is cut away for that purpose; it is furnished with a pole and also shafts, to suit either cart or carriage horses. *f f* are the handles working the shaft *e e* by means of two levers. When not in use, the handles are kept in their present position by the forked bar *g*. The suction-pipe screws on to the nozle *h*, otherwise closed by a brass cap. There is a screwed nozle *i* on each side, for attaching the delivery hose, which may be fixed on to either side, or both sides, at pleasure. The pockets *d* carry two six-foot lengths of suction pipe, and two branch pipes, one long, the other short. The other equipments, generally about six forty-feet lengths of leather hose, rope, crow-bar, shovel, pole-axe, saw, &c., are stowed away in convenient order in the front and uppermost box of the engine. All being contained inside, and nothing hung on externally, this engine is exceedingly compact, and very elegant in appearance. The top of the engine forms an excellent seat for the firemen, their feet resting on the pocket *d*, while the driver occupies the box seat in front, guiding a pair of light horses, which will draw an engine of this kind at great speed. At *k* in the sectional portion is seen the sole, or sucking-piece, containing all the valves, and carrying the two working cylinders. At one extremity of the cistern the three-way suction cock *l* is screwed to the sole *k*; to the other end a brass tube is also screwed, forming a communication with the air vessel *m* and exit pipe *i*. *n* is the first or suction-valve chamber, divided into two compartments, each containing a valve, closed on the top by a plate of cast iron, fastened down with copper screws, a piece of leather being introduced between to make the joint water-tight. *o* is the second, or delivery-valve chamber, also in two compartments, closed in the same way as the former. The valves are brass plates, ground to fit the circular brass seat on which they rest; being accurately ground, no leather is required to make them tight. The whole valve is put together, and then slipped into grooves, cast in the side and bottom of the sole for its reception. If any of these valves should fail, it is only necessary to unscrew and remove the covering plate, when they can be got at without disturbing the other parts of the engine. In Newsham's engine, if one of the suction valves became deranged, the engine had to be taken completely asunder, before the defect could be remedied. *p* is one of the working barrels, six inches in diameter, with a seven-inch stroke, made of cast brass, carefully bored and screwed down upon the iron sole *k*, with copper screws, an intervening leather making the joint perfect. The piston *q* is of two circular brass plates, placed in strong leather caps, and bolted together. The top of the barrels is a little above the level of the cistern, so that when the latter is filled with water it may not run into the barrels, and wash away the oil with which the pistons are kept constantly covered. Projecting arms on each side of the main shaft *e*, work the pistons by means of slings within the piston rod, which is forked to the height necessary for that purpose, but ends in a cylindrical rod, working in a guide plate above *r*, which preserves the parallelism of the piston throughout its stroke. The main shaft works in brass journals at *s s s*. The sole *k* is made so as to form an inclined plane from *h* to *i*, which causes all the water to run out of the engine after it has ceased working. The principle of action in this engine is similar to that already explained while treating of Newsham's, and therefore requires no further mention here.

In the year 1793 Mr. Joseph Bramah took out a patent for a new fire engine, with sundry improvements and additions. This engine was essentially different in its construction from those already described. It consisted of a large horizontal metal cylinder, having a flanch at each end, to which two end caps or covers were screwed. These caps enclose all the working parts of the engine, and have brass bearings with stuffing-boxes in their centres, for carrying in an air-tight manner the working axis of the engine. Within the cylinder is placed a strong metal partition or radius, the lower edge being joined to the cylinder, and the uppermost edge, which is grooved, made so as exactly to fit

the circle of the latter. The axis is armed with two wings or fans, on each of which is placed a valve opening upwards, to allow the water to pass through them. These fans are made to move water-tight against the sides and end caps of the cylinder, by means of leather on their edges. When the axis carrying the fans is fixed in its place, the groove in the metal partition described above, is filled with hemp, or some other soft material, so as to press on the under surface of the axis, and cause it to move in a water-tight manner. The fans being a diameter of the cylinder, divide it into two parts, the lower of which is again divided by the radius partition into two compartments, in each of which an aperture is cut through the cylinder opening into the suction passages; these apertures, like those in the fan, are closed by valves opening upwards. A vibratory motion being given to the fans by means of levers on the axis, the capacity of the two lower compartments of the cylinder becomes alternately enlarged and diminished; the consequence of this is, that water becomes drawn up into the cylinder, gets above the fans on either side, and is then forced out through the exit pipe, the stream being rendered equable by means of a spherical air vessel placed on the top of the cylinder. This was a novel and ingenious contrivance, and produced a very compact engine; a great drawback, however, upon its advantages, was the difficulty of packing and making it water-tight in the first instance, and the still greater difficulty of keeping it so for any length of time, if much used.

Subsequently Mr. Rowntree introduced an engine, in which he attempted to embody all the advantages of Bramah's engine, and to avoid its defects. Mr. Rowntree's principal improvement consisted in the employment of one fan, a radius of the cylinder, instead of two; the vibration of the fan took place in the lower half of the cylinder, the partition being placed above. Mr. Rowntree, however, succeeded but imperfectly with his engine, which has been greatly surpassed by a more recent invention by Mr. John Barton, which is decidedly the best engine hitherto constructed on the vibratory principle.



The accompanying drawing and description will convey an accurate idea of Mr. Barton's engine, and show the principle of action in this, as well as in the two former contrivances. The figure affords an end view of Barton's engine, mounted on a suitable cistern upon wheels. *a* is the cylinder, or working barrel, of brass or iron: *b* is the fan or piston, which, like Rowntree's, is a radius, but his was placed below the centre, while Barton's is situated above. The fan is composed entirely of metal, on the expanding principle, with springs and segments, as in Barton's metallic pistons. *c c c c* are four valves, all opening upwards; *d* is the air vessel, with the exit orifice at its lower part; *e* is the cistern, which may be kept full of water for immediate use on the breaking out of a fire. This engine, like all the former, is capable of working from a pond, &c. by means of a suction hose, as well as from water poured into the cistern, the supply, as in Newsham's engine. being regulated by a three-way cock placed within the cistern. The engine is worked by the elevation and depression of the handles

h h, connected with the axis of the fan *b*, which vibrates backward and forward in the upper part of the cylinder, and delivers at each stroke nearly one-half of its contents, and may be regulated so as to give more or less, as required. The working of the fan or piston *b*, being perfectly air tight, tends to produce a vacuum below, on that side of the cylinder *a* where the handle is elevated, and the pressure of the atmosphere causes water to rush up into this space. During this stroke the air that occupied the other side of the cylinder has been partly expelled, and this space, on the second stroke being made, is filled with water, while that already on the other side of the piston is forced up into the air vessel, and thence through the exit pipes in a continuous jet.

A very compact and convenient fire engine has lately been invented by Mr. Baddeley, consisting of only one cylinder placed horizontally, and working on the principle of De la Hire's double-acting pump. The ordinary up and down motion of the handles, by means of a simple contrivance, causes the piston to traverse backward and forward within the cylinder, each side being alternately filled with water which the returning stroke expels. There are two entrance valves lying at the bottom of the cylinder, one at each end, and two exit valves, situated immediately over the former. The water enters at the bottom of the cylinder, and is discharged at the top, the stream being equalized by a globular air vessel. The inventor considers the advantages of this engine to consist in its compact form, great strength, and durability; that it has fewer working parts, is lighter, and has less friction than any other engine of equal power.

Of all the engines hitherto constructed and worked by manual labour, the floating fire engine is the most powerful. Engines of this kind generally consist of three cylinders, working into an air vessel of large dimensions, and are built in appropriate barges. They are put in motion by the power of from forty to fifty men, applied to four long revolving cranks, which, by suitable machinery, work the three pistons. These engines will throw a column of water, one inch in diameter, upwards of a hundred feet high. They are advantageously employed on the river and in docks, where an abundant supply of water can always be depended upon.

These engines, however, have been greatly surpassed by the fire engines recently constructed by Mr. John Braithwaite, worked by steam power. The last of this kind, the Comet, built for the Prussian goverment in 1832, had two working cylinders ten inches and a half in diameter, with a fourteen-inch stroke, the steam cylinders being twelve inches in diameter. When working with a steam pressure of seventy pounds upon the square inch, and making eighteen strokes per minute, this engine threw a jet of water, an inch and a quarter in diameter, nearly one hundred and twenty feet high. The same power gave two jets of seven-eighths of an inch, and afterwards four of five-eighths of an inch, an elevation of about eighty feet. The consumption of coke was three bushels per hour, and the average working of the engine was calculated to be equal to the discharge of between eighty and ninety tons of water per hour.

Numerous attempts have been made to condense a powerful fire engine into a small compass. In this respect Capt. Fisher, R.N. appears to have been most successful; his engine, on Newsham's principle, consisting of two five-inch cylinders, with eight-inch strokes, and an air vessel situated between them, was comprised within a box the size of an ordinary tea chest, exclusive of the handles, which fixed on the outside, and served to carry the engine by. The purposes for which this kind of engine is suitable are so few, that they have not been very extensively used; for the local purposes only of mansions, manufactories, or on ship board, can they be advantageously employed.

Much ingenuity has been exercised to construct a fire engine on the rotatory principle, but without success. An ingenious one of this kind was the invention of Mr. Rangeley, for which he took out a patent. It consisted of two fluted rollers, working into each other, while their opposite sides worked in semi-cylinders, with which they were in close contact, the ends of the rollers being similarly circumstanced; each space between the flutings came up filled with

water, which was discharged by the flutings exactly fitting into each other on the descending side. In this, however, as in all the other rotatory steam and fire engines, it was found to be practically impossible to construct an engine sufficiently water tight to stand the great pressure to which they are subject, without incurring an excessive and destructive amount of friction.

FIRE ESCAPE. Perhaps few subjects have more extensively engaged the public attention, or exercised so much ingenuity, as the best mode of rescuing individuals from death by fire. Notwithstanding the varied talents that have been directed to this object, it is a singular fact, that no invention has yet been

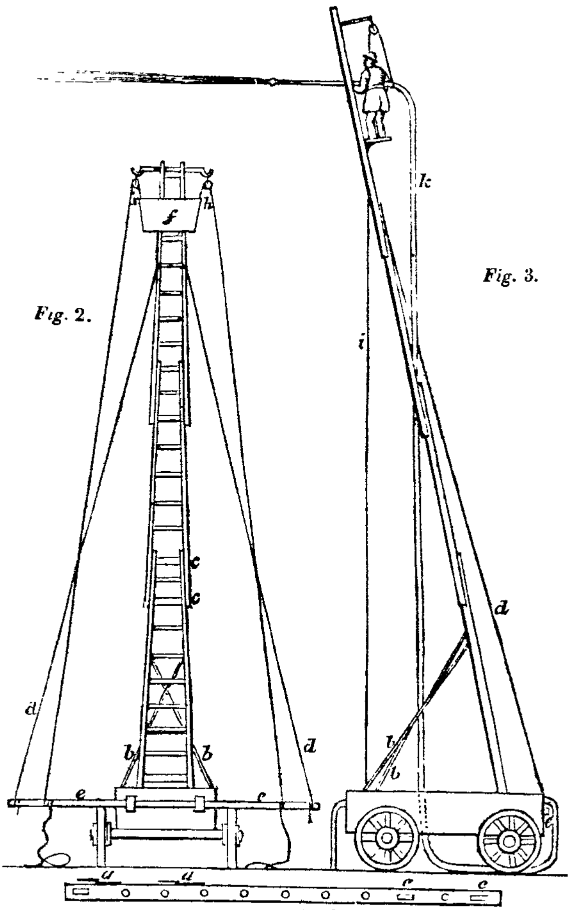


Fig. 1.

produced so universally efficient as to supersede all others, or to induce the belief that the limits of perfection have been attained. Many excellent and ingenious contrivances have been produced, most of which will be found embodied in the following classified description. Fire escapes may generally be divided into three classes, viz. ladders, portable escapes, and carriage escapes. With the common fire ladders all must be well acquainted; they are made of different lengths to reach a first, second, third, or fourth story window. When of the largest kinds they are generally furnished with iron guides or hand-rails

at the sides, and also with a contrivance for raising them. This contrivance consists of a short conical iron tube, jointed to one of the upper rounds or steps of the ladder; a long pole fixes into this tube, and affords great facility in raising the ladder. A well-made ladder of bamboo, from its extreme lightness, combined with the requisite strength, has been considered by some persons admirably adapted for the purposes of a fire escape. Another form of ladder, and one that is at present very successfully employed, consists of short lengths, from eight to nine feet long, which fit one on the other to any required extent, by a strong, but simple joint, in the same way as scaling ladders. The advantages of this kind of ladder are, great portability and convenience, with all the practical utility of the longest and most unwieldy ladder. Mr. Gregory, whose numerous fire escapes have attracted deserved attention, has constructed a great variety of ladders; among them is a very pretty ladder, in two parts or lengths, one sliding upon the other, and sustained at any required elevation by a simple contrivance. A cradle is attached to this ladder, for the rescue of timid or infirm persons; the whole is of a convenient size for carrying or stowage, and is very easily managed. Mr. Gregory's patent ladders are exhibited in the engraving on the preceding page. *Fig.* 1 is a side view of one of the ladders, nine feet in length. *Fig.* 2 exhibits three of these ladders connected together, and applied as a fire escape, with a light car or cradle, raised by ropes *h h*, working in pulleys attached to the top of the ladder. *Fig.* 3 represents four of these ladders raised, for the purpose of elevating the fireman, and enabling him to direct the stream of water from the engine most effectually upon the fire. A set of these ladders may be placed on a light hand carriage, or might accompany each fire engine. On reaching a conflagration, the lower ladder is first raised, and the feet secured in their place by a bolt passing through them and two blocks, placed upon the engine for that purpose. The iron stays *b b* crossing each other are hooked into staples fixed in the back of this ladder. The first ladder being thus firmly fixed, a man mounts it and attaches another on the top of it; a third, fourth, or a fifth, may in this way be added, until the required height is obtained. When the height is considerable, two guy ropes *d d* are employed, to preserve the ladders in the proper position. For this purpose the back of the carriage is provided with two large square staples, through which the bar *e* is thrust; to the ends of this bar the ropes are made fast, as shown. The ladders are each precisely alike, so that all fit one another; they are connected by the following simple and effective contrivance. Two long hooks or half-staples *a a* are fixed on the hook of each ladder by means of an iron strap, and riveted through; each ladder is provided with two flat steps *c c* at its lower end, which drop into the two hooks and make a firm and secure joint. Rope ladders have sometimes been employed as fire escapes; the most common kind consist of strong rope sides, with wooden steps; circular pieces of wood are sometimes added to the ends of the steps, to keep the ladder from walls, &c. In Edinburgh wire chain ladders are employed with great success, being used by men duly trained for that purpose. The principal difficulty with all ladders of this description, is in raising them to the windows where they are required; this difficulty has been surmounted in the rope ladder of Mr. A. Young, the most ingenious and useful contrivance of this kind with which we are acquainted. It consists of a number of rounds A, *Fig.* 2, (in the engraving on the following page,) which form the steps of the ladder by being united with two ropes B B; these are suspended from an iron frame C, terminating in hooks *a a*, which can very conveniently be lodged on the sill of a window, and thus form a secure support for the ladder. The principal peculiarity of this contrivance consists in making the ladder, so that the rounds or steps can be put together as shown at *Fig.* 1, forming a pole by which the frame *c* can be raised up to a window from below. To effect this, the ends *e* of the rounds A have ferules fitted fast upon them, and the other ends *f* are reduced so as to enter the cavities of the ferules, which project beyond the end of the wood, thus forming sockets for their reception. The iron frame *c* at the top has a projecting pin *d*, which fits into the socket *e* of the upper round; this supports it at the top. The small end of this step is inserted into the ferule of the second, which

is again fixed to the top of the third, and so on to the bottom. In this way a pole is formed, as in *Fig.* 1, of all the steps of the ladder joined together, by which means the hooks at the top of the iron frame may be raised up to a window sill, and then a single jerk or pull at the lower end disunites the staves from one another, and they assume the form of *Fig.* 2, ready for ascending or descending. The side ropes of the ladders B B are composed of three small lines plaited together, which method gives the means of fastening the staves very securely to them; this is shown by *Fig.* 3. A hole is bored through the stave at the place where the rope is to be fixed, large enough to receive one of the three lines, and a groove is turned round outside of it at the same place. One of the lines is passed through this hole, the other two are taken round in the groove so as to surround the stave, then all three, being plaited together make a firm connexion. The frame *c* at the top has two iron rods *b b* fixed to its sides, which are useful as hand-rails to any person getting out of a window on to the ladder. The whole rolls up into a compact bundle, and is easily carried about. A ladder on the same principle may also be constructed entirely of metal, by using wire chains, and metal tubes for the steps. Mr. Young received a silver medal and fifteen guineas from the Society of Arts for his invention.

Fig. 1.

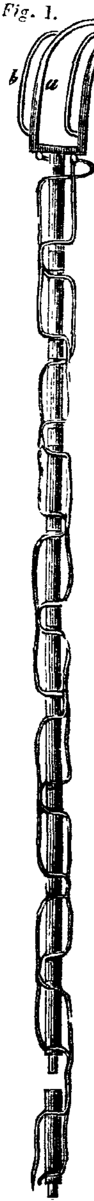


Fig. 2.

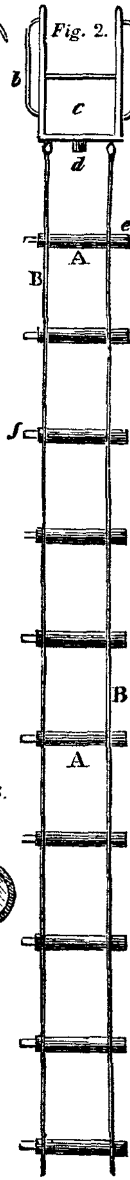


Fig. 3.

Mr. Gregory constructed a very complete rope-ladder escape, which was supported on the window sill, parapet, &c. of a house, by a hook of ingenious workmanship, composed of two sides or arms, bent into a form very closely resembling the external figure of the human ear, from that circumstance called the ear hook. The two sides of this hook were held together by three horizontal iron rails or bars. This simple, original, and effectual mode of attachment admits of universal application, without any previous provision for that purpose; it firmly embraces alike the thickest and thinnest walls, and when once fixed, no downward force can separate it from its attachment, but by tearing the hook asunder. To this hook was attached a neat, well made rope ladder, to which a sliding cradle was adapted, the rope by which the cradle was worked passing over the central bar of the ear hook.

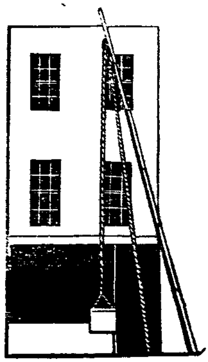
The next class of fire escapes, comprising those of a portable description, is a very numerous one, and may be said to commence with a simple rope made fast to something within the room, by means of which a descent might be effected; it has been considered an improvement to knot the rope pretty closely, and descend by alternately changing the grasp, instead of letting the rope slip through the hand; it is but a limited number of persons, however, who could escape by these means. It

has therefore been suggested to attach a sack to the end of a rope of sufficient length, into which females, children, &c. might be put and lowered in safety, their descent being regulated by drawing the bed close to the window, and passing the rope once or twice round the bed post, which would generate friction enough to make the descent easy, without much exertion on the part of any person. Several improvements have been made upon this rude and simple apparatus, consisting in general of a cradle in lieu of the sack, made of a convenient form and suitable material, and in running the rope through a pulley hooked to a staple provided for that purpose; a guide rope is also attached to the bottom of the cradle, which enables it to be pulled aside from flames issuing from the lower windows, and from railings, areas, &c. In some cases the pulley is supported by a grappling hook thrown into the window. Escapes of this kind have been constructed by Messrs. Cobbin, Cook, Fox, Hesse, Merryweather, Read, and some others, all similar in principle, but differing slightly in detail. Mr. Gregory employed a stout rope, forty feet long, having a hook at the top, and a pulley within a few inches of it; a cradle slides upon this rope by means of two rings, one at the top and the other at the bottom of it. Another rope, twice the length of the former, passes over the pulley, and is fastened to the upper part of the cradle; by this rope the persons below raise or lower it, until the whole of the inmates of the house are extricated. In this escape the oscillations, as well as the rotatory motion, which occur in some of the former contrivances, are both prevented.

Mr. B. Rider a short time since exhibited a simple rope fire escape, consisting of a stout hempen rope sallied with worsted, having at one end a swivel spring catch, by which it could be instantly attached to a bed post, chest of drawers, bar of a grate, &c. Upon this rope was placed a stirrup or friction seat, with three rings, through which the rope passed; these rings were not placed perpendicularly above each other, but stood in a curved direction, so as to cause considerable friction, and check the too rapid descent of the parties; for one individual, with very little exertion, could, by means of the friction seat, descend with another person in his lap. A contrivance was also appended, for instantly fixing a secure noose under the arms, to be used when the friction seat was not employed.

Mr. Davies invented a rope fire escape, possessing in an eminent degree the essential qualities of simplicity, efficacy, and portability. It consists of a long rope doubled, the two ends of which are secured to a strong iron hook, for the purpose of attaching it to a ring bolt screwed to the sash frame, or a beam in the ceiling. A number of loops, made of strong girth web, slide upon the double rope, by means of short copper tubes or eyes; these loops are also equipped with cloth slides. This, with a jointed rod for raising it to a window, comprises the whole of the apparatus. The mode of using this escape is as follows: the end of the double ropes at which the sliding loops are all collected, is placed upon the forked extremity of the uppermost joint of the rope, a second is added, and so on, till the necessary elevation is obtained. The persons above having secured the hook to some suitable object, those below hold the ropes asunder, thus forming a triangle, the apex being at the window, and the base in the street. One of the persons above then takes one of the loops, and passing it over his head and shoulders, fixes it under his arms; he then gets out of the window and commits himself to the rope, down which he slides to *terra firma*. As the ropes are in contact at the window, the descent is at first rapid, but as the person gets lower, the greater divergence of the ropes gradually arrests his progress. There should be at least six or eight persons holding the ropes, and they should be kept as wide apart as circumstances will permit; the base should always be upwards of three yards. Females, children, &c. may be lowered by this escape with perfect ease and safety; for, by bringing the cloth slide on the loop close to the body, the person descending cannot quit the loop till released by withdrawing the slide. Mr. Barnard had previously proposed the employment of a wicker cradle sliding on divergent ropes, but this arrangement is inferior to that of Mr. Davies in practical convenience and efficacy. The principal difficulty attending the use of portable fire escapes, is in

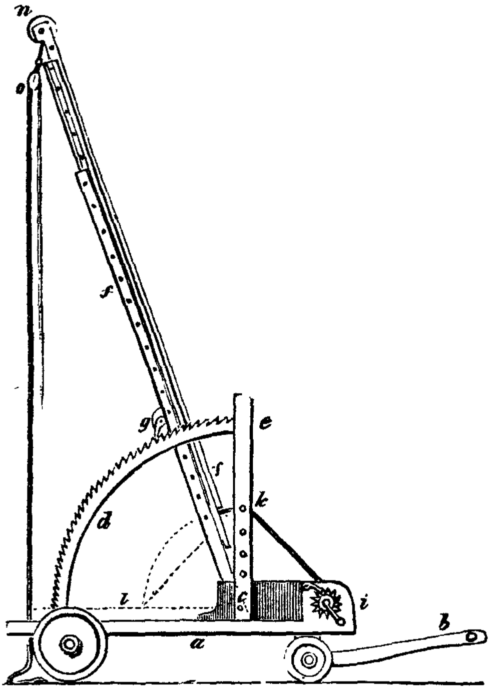
establishing a communication with the persons in danger; the most usual method of effecting this object is by rods about six or eight feet long, connected either by fishing-rod or bayonet joints, or by screws, as in the escapes of Messrs. Davies, Glass, Merryweather, and several others. The accompanying sketch shows a series of rods connected in this manner, which not only raise but also support a pulley upon which a cradle is worked; this arrangement, however, requires strong, and, consequently, very heavy rods, and therefore cannot be much recommended. Mr. Gregory effected a communication by means of a walking stick with three extending joints like a telescope, by which a line was handed to the persons in danger from the window of an adjoining house. Others have suggested the idea of dropping a line from the tops of the houses on each side of that on fire, which, attached to a rope, or escape of any kind, would enable it to be raised to those requiring its aid. Some persons have proposed to throw a ball with a line attached, into the window from the street, and thus form the desired connexion; this, however, is a difficult and random mode of proceeding, and by no means to be relied on in the time of danger. The Edinburgh firemen use a cross-bow, and a three-ounce leaden bullet, attached to a fine cord of the very best materials and workmanship, 130 feet long. The bullet and cord are thrown over the house by the cross-bow; to this cord a stronger one is attached, and drawn over the house by the former, and so on, until a chain ladder or escape is eventually elevated. To act upon this plan, however, with any good chance of success, requires the men to be regularly trained for the purpose, as they are in Edinburgh, where they are exceedingly skilful in the management of all their fire machinery.



Mr. Buston introduced a fire escape, consisting of a large strong canvass sheet, with loops all round to hold on by; this being held under the window at which any person is situated, by eight or ten persons, the party above leaps out of the window into the middle of the sheet, which catches him uninjured. Although this is by no means the most pleasant mode of escape, nevertheless numberless experiments have proved it to be a safe and effectual one. As this escape takes up but little room, and is ready for use in a few seconds, it is well adapted to be carried by the fire engines, and most of those in London are now provided with one of this kind.

Having thus briefly noticed the most celebrated fire escapes of a portable nature, we proceed to describe those of a larger kind; and first of carriage ladders. In the year 1809 Mr. John Davies submitted to the Society of Arts a fire escape, which consisted of three ladders connected to, and sliding upon, each other, by means of ropes worked by a small windlass; a second windlass raised and lowered a cradle, supported by ropes passing over pulleys at the top of the uppermost ladder. This machine was mounted upon a low four-wheeled truck, drawn by a horse or by six men. Subsequently, Mr. Gregory greatly improved upon this escape; he employed three ladders sliding on each other, which, when lowered, were balanced horizontally upon a convenient frame mounted on a light four-wheeled carriage. When in this position they are capable of being run under low gateways, &c. with great facility. The ladders are brought into the perpendicular position, and then raised by a small windlass in the front of the machine, to any required height between ten feet and forty; the ladders are then inclined towards the window, upon the sill of which the top may be made to rest. To obtain a greater elevation than forty feet, one or more joints can be carried up and affixed, in the manner already described under the head of Portable Ladders. A cradle accompanies this machine, for the assistance of those who cannot descend the ladders. Mr. Gregory's ladder escape has been but partially employed for that purpose; as a valuable and convenient ladder, however, it has been very extensively used by architects and others.

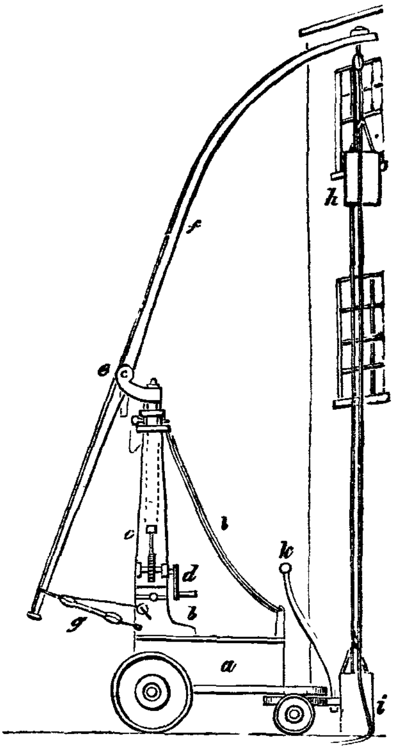
Mr. John Hudson, the founder of a short-lived society for preventing loss of life by fire, in 1829, constructed an escape-ladder, differing in some respects from that of Mr. Gregory, although upon a similar principle. The following is a side view of Mr. Hudson's apparatus; *a* is the carriage mounted on four



wheels, the front pair of which turn with their axis and handle *b* under the carriage, for the facility of guiding, stowage, &c.; *ff* are three ladders sliding in grooves one within another. The foot of the lowest ladder is hinged to a revolving centre in the middle of the floor of the carriage; *d* is an arched frame forming the quadrant of a circle, with ratchet-teeth on its edges, in which drops a pall or click *g* on a cross bar fixed to the back of the lowest ladder. The ladders usually lie in a horizontal position, as shown by the dotted line *l*; the palls and ratchet-teeth prevent the ladders from falling back while being elevated. In order to place them in the oblique position for use, they may be elevated by hand, or more easily by turning the windlass *i* round the barrel of which the rope *k* is wound, and the other end of it fastened to the ladders at about three feet above the floor. The ladders being thus brought to the position represented in the engraving, the motion of the windlass is continued, which winds off the rope from the ladders, and elevates them successively one above the other, until they attain the greatest height. The rope *k* passes through a pulley near the bottom of the lowest ladder, then over the top of it to the bottom of the next, and then over the top of the same to the bottom of the uppermost ladder. The pivot to which the ladders are hinged, is for enabling them to be veered round when it would be inconvenient to turn the carriage. The horizontal position is given to the ladders for enabling the machine to be conveyed through low passages, &c. There is a roller *n* at the top of the ladder, to prevent friction when moving up against a wall, and a tackle fall at *o* for cradles, &c.

Mr. Joseph, who entertained a strong objection to the use of a connected

series of ladders, submitted the following novel contrivance to public inspection :—*a* is a carriage capable of being drawn by two men, on which is fixed an elevated part *b*, sustaining a column of wood *c*; within this there is a smaller column of iron, capable of being raised by a rack and pinion, acted upon by the winch *d*; on the top of this internal column is an iron arm *e* on a swivel, having a cleft at its extremity to receive the long bar or lever *f* fastened to it by a bolt. The lower end of this bar is secured to the carriage by a pulley-tackle, which admits of an easy and secure adjustment at pleasure; to the upper end of this bar is suspended the cradle, &c. in the usual manner, with guy ropes to guide the cradle in its descent; *k* is the handle for drawing the carriage. There is a small rope ladder at *l*, and a bolt and chain at the top of the column, for fixing the internal pillar (which has a range of eight feet) at the required elevation. The pillar has a joint near its base, by which it is turned down into the horizontal position whenever it is required to pass under gateways, &c.

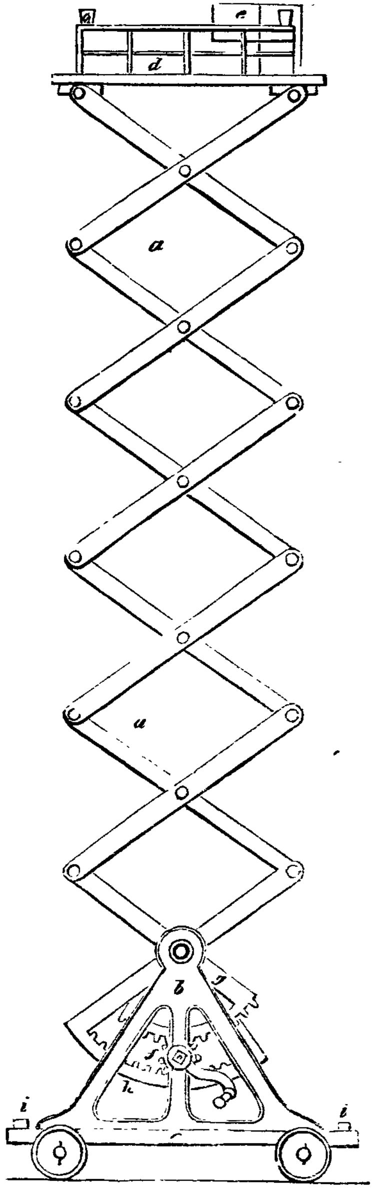


In the year 1813, Mr. Thomas Roberts received a reward from the Society of Arts, for a "speedy elevator and fire-escape," of a very complex description, on the principle of the lazy-tongs; the same principle has since been employed under various modifications by numerous persons, and most recently by Mr. Doyle. The engraving on the following page represents Mr. Doyle's machine; *a a* exhibiting the combination of levers on one side of the machine; *b* is the frame that holds the lower pair of levers, and wherein the moving force is applied; *c* the carriage on four wheels, drawn by a handle not shown in the engraving; *d* is a stage or platform at the top of the machine, on which a fireman or other individual is raised to rescue the persons from the house on fire; at *e* there is a folding-bridge or gangway, to be projected into the window of a room; at *f* is a toothed pinion; *g* is a toothed quadrant, welded to the lowest lever-bar on one side, with its teeth taking into those on the upper side of the pinion; at *k* is another quadrant, the teeth of which take into the lower side of the pinion; motion being given to the pinion by the winch, the two quadrants are moved in opposite directions, and the series of levers are simultaneously operated upon in like manner, opening and shutting like so many pairs of shears, thereby drawing them all up closely together, or expanding to the extent of nearly their whole length. In the accompanying cut the machine is represented as only expanded to half the height it is capable of being extended. On the other side of the machine, there is, of course, a similar set of levers; they are connected to those already described, by cross horizontal bars, the ends of which form the pivot joints on which the levers turn. The opposite side of the lower part of the machine is also a counterpart of that represented, and the power is connected by a common axis to the opposite pinion. Although the principle of the movement is, perhaps, the best that could be devised for the purpose, the practical difficulties of executing such a

machine on a large scale, have, we are informed, been found insurmountable, an attempt to construct one having failed.

Mr. Gregory, some few years since, patented a "portable derrick fire-escape," which consisted of three square wooden pillars, sliding one within the other, mounted on a convenient carriage; the uppermost carried a pulley for raising a cradle, &c. The pulley was elevated by a windlass and rope connected with the pillars in the same manner as employed for raising his ladders.

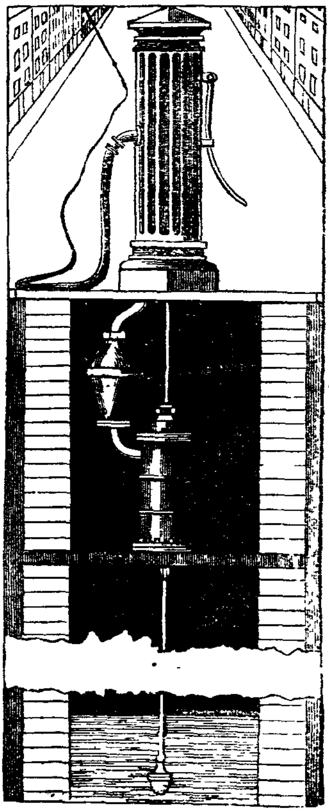
Mr. Rose, of Manchester, constructed a fire-escape composed of an upright frame, fronted on a four-wheeled carriage; a second frame sliding within the former, carried at its top a small railed platform or gallery, in which people were received from the windows of houses; or it was occupied by a fireman with the branch of an engine, which enabled him more effectually to throw the stream of water upon the fire in lofty buildings. The sliding frame was raised by two chains attached to its lowest end, and carried over pulleys at the top of the first frame, to a windlass in the body of the machine; a ladder formed a communication between the body of the machine and the platform when it was in its lowest position.



Besides the escapes already noticed, there is yet another kind, which may be very properly designated "domestic fire-escapes," as they are intended solely for the use of the family in whose house they are placed. Some of the best of this class are those in form of a chair, sofa, or other convenient article of furniture, and stand in the recess of a window, outside of which they are soon placed, and constitute excellent fire-escapes, with every convenience necessary for a safe descent. Mr. Witty received a reward from the Society of Arts for an admirable escape of this kind. These machines, however, do not generally obtain, for the mass of the people are too indifferent to this subject to provide themselves with escapes, but rather choose to trust to the chance of obtaining external aid. Various expedients have been resorted to, and different plans may be adopted to effect an escape from fire, according to circumstances. Egress can sometimes be made at the top of a house, either by a door, or by an opening made in the

roof with a poker for the purpose. Sheets and blankets tied together and fastened to the bed-post, or the bed-cords, attached in the same way, afford the means of descending; the feather-bed, &c. thrown out, serve to break the fall when jumping from the window as the last alternative. With a little contrivance, women and children may be lowered by means of the bed-clothes. Upon these occasions, all depends upon the persons in danger retaining so much presence of mind as will enable them to avail themselves of the best means in their power; and it often happens that pressing danger develops a great deal more ingenuity and intrepidity in individuals, than they have previously taken credit for.

FIRES, Extinguishing of. The most suitable and convenient material for extinguishing fire is water; but when that cannot be speedily obtained in sufficient abundance, it has been proposed to increase its extinguishing property by the addition of various substances. M. Van Aken, a Swede, employed an antiphlogistic composition of water holding in solution sulphate of iron, sulphate of alumine, red oxide of iron, and clay, with which he performed several successful experiments. Some persons have recommended the employment of simple solutions of either of the following substances—alum, common salt, pearl-ash, and several other salts and alkalies. Other experimentalists, on the contrary, especially M. Van Marum, have contended, with much apparent truth, that water alone, when properly and judiciously applied, is nearly as efficacious in extinguishing fire as any of the above compounds. Carbonic acid gas, sulphuric acid gas, and steam, have likewise been suggested as applicable to the extinction of fire; there is, however, much practical difficulty, and great inconvenience in employing either of these substances for such a purpose; with respect to the latter, some extensive and well-conducted experiments, recently performed by Mr. Waterhouse, at Preston, in Lancashire, have shown that steam will speedily extinguish moderately small bodies of flame, but does not possess the power of preventing a low or charring combustion, and that steam impelled against a large fire increases the violence of the combustion in a remarkable degree. Water, however, is so universally diffused, that all other modes of extinguishing fires have fallen into disuse. There are many ways of applying this fluid to the purpose now under review, the most useful of which we proceed briefly to describe. The simplest contrivance for extinguishing fires, is by means of an elevated reservoir or cistern, a pipe from which proceeds through all the floors of the building, with a cock and screwed nozle in each, to any of which a flexible hose and director can be affixed. On turning the cock, a jet of water rushes out with a force proportionate to the height of the reservoir, which can be thrown into that part of the premises where the fire is situated. This arrangement is particularly useful in large manufactories or warehouses. The principal advantage of this plan, is the great facility with which one person can apply this remedy, the labour having been previously performed. If the fire is so extensive as to require more water for its extinction than is contained in the reservoir, the supply must be



maintained by pumping. In lieu of the reservoir and system of pipes, some persons prefer fixed pumps, drawing their supply of water from a well. The engraving on the preceding page represents a stationary fire-pump of this description, as erected in various places by the late Mr. Russell, of St. John Street, London. It consists of a lifting-force pump, with an air-vessel to equalize the stream between the strokes, placed in a deep well. The nozle of the pump is screwed for attaching one or more lengths of leather hose, according to the distance of the fire; the handle is forked to allow several hands to work the pump. The advantages of this and other kinds of stationary engines, consist in the promptness with which they can be got into action, and the certainty of obtaining a sufficient supply of water: one disadvantage is, that their usefulness is confined to a comparatively limited space. In some late experiments, one of these pumps, erected at Aldgate, delivered a stream of water with considerable force at the distance of sixteen hundred feet from the source of supply.

Of all the portable contrivances for extinguishing fires, perhaps that invented by Capt. Manby is the most convenient, and is very ingenious. This apparatus consisted of a copper vessel, two feet long, and eight inches in diameter, capable of holding four gallons. A metal tube, a quarter of an inch in diameter, passed internally from the top to within half an inch of the bottom of the vessel, furnished at the top with a stop-cock and jet-pipe one-eighth of an inch in diameter. Three gallons of a saturated solution of pearl-ash in water being put into one of these vessels, the jet-pipe was removed, and a condensing syringe afforded in its place; as much air as possible was then pumped into the space remaining above the fluid: the stop-cock was then turned, and the condensing syringe exchanged for the jet-pipe. In this state the apparatus formed the well-known artificial fountain in pneumatics; on turning the cock, the elasticity of the condensed air reacting on the surface of the fluid, forces it out at the nozle in the form of a violent jet. Six of these vessels were placed in a light hand-cart, with which a man could run at a good speed. On reaching the fire the man takes one of the charged vessels from the cart, and slings it in front of him by a strap passing over his shoulders; he then enters the building, and placing himself as close as possible to the fire, turns the cock, and discharges the contents of the vessel on the flames; by the time the first vessel is expended, others will have been conveyed to the man, who discharges them in succession. All fires, even the greatest, have small beginnings, and when early discovered, are easily kept under or suppressed. Capt. Manby's fire-cart appears well adapted to check the progress of fires, if not by entirely suppressing them, yet by keeping them within the range of easy extinction by more powerful means, which cannot be so expeditiously applied.

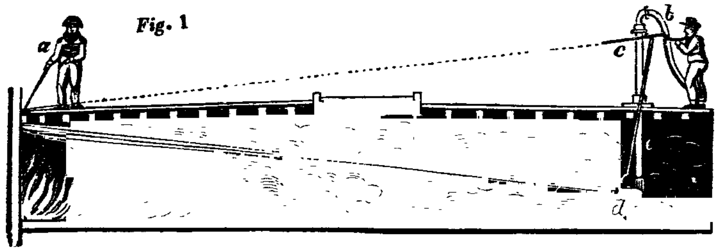
Fire-engines are now common in every civilized country; the several kinds of these useful machines having been already fully described, it will only be necessary in this place to offer a few practical remarks on their management. In bringing up, placing, and setting a fire-engine to work, great judgment is requisite, and much will always depend upon the acquaintance of the parties employed with the duty they have to perform. Great activity is required in combination with skilfulness; six good hands will, at any time, get a large fire-engine to work through two or three forty-feet lengths of hose in about two minutes, supposing water to be at hand. An engine being set to work, its efficient performance will depend entirely upon the manner in which the stream of water is directed. The old method was to throw the water into the windows at random; latterly, however, a more rational mode of operating has been adopted, and one, the advantage and efficacy of which was strikingly exemplified by the experiments of M. Van Marum, before alluded to. The only successful mode of using a fire-engine, is to take the director or branch-pipe into the building, as near as possible to the fire, and be sure that the stream of water strikes directly upon the burning materials; this cannot be too often or too anxiously inculcated on every person using a fire-engine. Every other method not having this for its fundamental principle, will, in nine cases out of ten, utterly fail. When the water is thrown into the building hap-hazard from the street, it is impossible to say if any of it touches the parts on fire or not, unless the flames appear at the

windows. On taking the hose and branch pipe inside the building, besides the advantage of the water striking directly upon the fire, there is a great saving in the article of water itself; the whole quantity thrown by the engine is usefully and advantageously applied, and no more is thrown into the building than is absolutely necessary to extinguish the fire. If, on entering an apartment, the flames are found to cover a considerable space, the thumb should be placed partly over the aperture of the nozle, which will spread the stream of water according to the pressure applied, so as to wash a large surface at once. In encountering fires at close quarters in this manner, much inconvenience arises from the smoke and heat; to avoid the former, by far the most annoying and dangerous of the two, it becomes necessary to kneel or lie down, so that the fire may be clearly seen and the water thrown upon it. While in a recumbent posture, a person will generally be able to respire air comparatively pure, though standing upright, suffocation would be inevitable: the purest air is always the lowest.

Mr. Roberts, a miner, invented a "hood and mouth-piece," which enabled the wearer to enter premises when on fire, through the most dense smoke, and rescue human life and property, or apply the most eligible means for extinguishing the flames. Mr. Roberts's apparatus is shown in the accompanying engraving, which is a side view, as it appears on the wearer. It consists of a leather cap or hood *a*, which entirely covers the head and face, with strong glasses before the eyes. The lower part of the hood is padded with soft cotton, covered with wash leather, which being drawn tight round the neck by a strap and buckle, excludes the surrounding air. The upper part of the proboscis *b* is of sufficient capacity to include the nose and mouth of the wearer, and forms the channel through which he respires. A trumpet-mouthed orifice is formed at *c*, provided with a good cork stopper, which is secured by a small brass chain; the use of this appendage is to afford a ready relief to the lungs, without taking off the hood when the wearer goes to the door or window of a building on fire, for the purpose of respiring a purer atmosphere, or to consult with persons on the outside. Below this part is attached, by means of an union joint, a flexible tube *d*, about two feet six inches long,

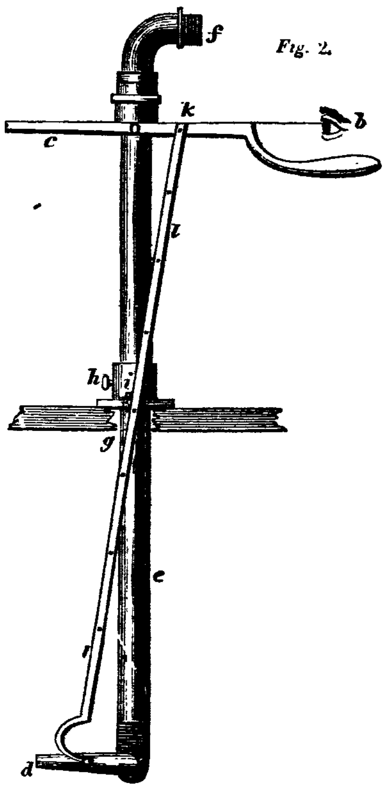
and terminating in a funnel five inches in diameter, in which is contained a sponge saturated with water. The flexible pipe is kept distended by a spiral coil of wire, and the straps *e e* are for the purpose of buttoning it to the dress of the wearer, so as not to encumber him, or impede his exertions. The operation of the apparatus is as follows:—The gaseous and other noxious matters

Fig. 1



which exist in the apartment, are, by the act of inspiration, obliged to pass through the funnel of the tube, where they are absorbed and neutralized by the liquid contained in the sponge, and the air is sent up to the lungs in a pure sate. The efficacy of the apparatus has been repeatedly proved, in the presence of numerous scientific individuals, amidst the most dense smoke, arising from the combustion of wool, wet hay, wood shavings, &c., besides large quantities of sulphur, in temperatures varying from 90 to 240° of Fahr.

Fig. 2.



To obviate, in some measure, the necessity for entering the apartment in which the fire is raging, Mr. George Dodd invented and patented an ingenious contrivance, consisting of a peculiar arrangement of levers and joints connected with the hose of a fire-engine, by which the operator may direct a jet of water to any unseen part of the interior of a ship or house on fire. This will at once be understood on reference to the above engraving, *Fig.* 1, wherein a person at *a* is pointing to the spot where the fire is situated; the operator *b* then directs the lever *c* he holds, so as to point to that part; this movement causes the nozle *d* to point to the same place, and, consequently, the utmost effect in extinguishing the fire is produced, which is, of course, greatly accelerated by excluding the admission of fresh air. The annexed *Fig.* 2 exhibits a part of the above on a larger scale, showing more exactly the construction of the apparatus by which these effects are produced; *e* is the branch pipe of a fire-engine, of a peculiar form, the hose being screwed on at *f*. If there is no bull's eye in that part of the deck where it becomes

necessary to insert the apparatus, the carpenter would be directed to strike out a hole, as shown at *g*, through which the branch would be let down to the required position, when it would be made fast by turning the screw *h* in the ferule *i*, the aperture below being entirely covered by a large flanch at the bottom of the ferule, as represented. The lever *c* moves upon a fulcrum, or centre-pin, at the upper end of the branch pipe *e*, not affixed to the pipe itself, but to another ferule fixed thereon. To this lever is attached, by another centre-pin *k*, the long bar *l l*, which is connected by a pivot-joint to the nose pipe *d*. It will now be seen, that as the distance between the two joints in the nose pipe is the same as the distance between the two joints in the lever *c*, a corresponding motion will be produced when operated upon in any direction, upward, downward, horizontally, or obliquely; and as the connecting rod *l* is perforated with a number of holes, it may be attached in any part of its length to the lever *c*, so that the jet may play close under the deck, or far from it. There are several other modifications of the apparatus to suit different circumstances, but the above explains the principle of action of the whole, which appears calculated to prove useful in stopping fires on ship-board.

FIRES, Prevention of. Among the various modes which have from time to time been proposed for this purpose, the most useful and important are those relating to the manner in which buildings are constructed. The general principles to be attended to are simple and briefly stated, viz. the use of incombustible materials to the greatest possible extent, and the placing of those necessarily inflammable in situations and under circumstances the most unfavourable for combustion. The incombustible materials commonly employed in building are stone, brick, and metal; the combustible is timber, in all its various forms. Many ingenious expedients have been resorted to for the purpose of rendering wood fire-proof; solutions of muriate of ammonia, muriate of soda, sal ammoniac, borax, alum, and several other salts and alkalies, have this property to a certain extent. Professor Fuchs, member of the Academy of Science at Munich, invented a composition for making wood fire-proof, which consisted of ten parts potass or soda, fifteen parts fine silicious earth, and one part charcoal, mixed together with water. This composition, applied to the surface of wood, forms a vitreous coat, which effectually resists the action of fire. After some decisive experiments had fully established the efficacy of this plan, the Royal Theatre at Munich was protected by the application of this composition; the surface covered was upwards of four hundred thousand square feet, and the expense, it is said, did not exceed five thousand francs. The following is an English composition for the like purpose:—one part, by measure, of fine sand, two parts wood ashes, and three parts slacked lime, ground together in oil, and laid on with a painter's brush, the first coat thin, the second thick. This forms a very strong and adhesive coating, which is both fire and water-proof. There are, in general, however, many practical objections to the use of these preventives; and the more feasible method of obtaining the desired security appears to be in the judicious selection and skilful disposition of the materials most commonly employed. Bricks form the staple material for building in most of the towns in this country, and with them the external walls are usually constructed; where due attention is paid to the prevention of fire, the partitions will be of the same material. If circumstances permit it, brick arches will also be used for supports. When it is desirable, for the purposes of trade, &c. to support the walls on brestsummers, those of cast iron are employed. Pillars of the same material are also frequently used with advantage to support fronts of considerable length. In this way the skeleton or frame-work of a building is easily completed in a fire-proof manner. The next thing, then, to be attended to, is the floor; and here we find caution extremely necessary, as the security of the building depends greatly upon the manner in which the floors are constructed. In dwelling houses, floors of wood are essential to an Englishman's notion of comfort; nor is there any real difficulty in obtaining them of this material perfectly compatible with the end now under consideration. There is a particular description of floor occasionally used in Edinburgh, which, although not absolutely fire-proof, is certainly almost

practically so. It is composed simply of plank, two and a half or three inches thick, so closely joined and so nicely fitted to each other and to the walls, as to be completely air tight. Its thickness, and its property of being air tight, will readily be observed to be its only cause of safety. A floor of a somewhat similar kind has been employed in the neighbourhood of Manchester with success; the planks are about three inches thick, jointed and ploughed on the edges for the purpose of receiving slips of iron called tongues, that enter some distance into each board; this makes a tight and substantial floor, which, as well as the former, should be laid on iron joists. Great protection is capable of being given to boarded floors, by using a strong fire-proof cement for the ceilings; the plaster at present employed is so to a certain extent, but this may be greatly improved. If a fire occurred in a room protected in this manner, the chance is more than ten to one that it would burn itself out before it could ignite the building. It would be very difficult to set fire to the floor, from the natural tendency of flame and heat to ascend; it would be still more difficult to ignite the ceiling, from the resistance offered to the flames by cement, iron joists, and, finally, by the closeness of the flooring. If the fire should not, however, be entirely repulsed, still its progress would be so greatly retarded as to afford plenty of time for the successful application of the usual modes of suppression. Before quitting this subject, however, there are some kinds of floors veritably fire-proof, which could not with propriety be omitted. At Manchester, fire-proof floors have been constructed in the following manner:—the columns and beams are of cast iron, and are firmly secured in their places with wrought-iron bars that traverse from beam to beam. Upon a margin underside the beam spring arches of brick work; these are filled to a level on their upper side with hard rubbish, and then covered with flags or tiles.

Mr. Frost, builder, of Bankside, London, has succeeded in forming excellent floors and roofs to houses, of hollow earthenware tubes and cement, so combined as to form a floor as strong as one of timber, but perfectly fire-proof. The hollow tubes are square in the section, and are made of brick earth, prepared by machinery in a very superior manner; they are placed in strata in opposite directions, and cemented together. The floor or flat roof thus produced, is, in effect, one solid flag stone of the size required, but not one-fifth the weight of stone. The cement which Mr. Frost employs is thus formed: chalk is ground fine in a mill, and, as it is ground, mixed with water, which carries its lighter particles to a reservoir. Clay is ground at the same time, and, mixed with water, is conveyed in the manner before mentioned. This combination of chalk with about thirty per cent. of clay, is drained, and left to evaporate to dryness. The mixture is then broken up, burnt in a kiln, and after being ground to powder, it is closely packed in casks; in this state it will keep for any period, and may be sent to any distance. Mr. Frost's floors have many recommendations, and his cement affords a very convenient mode of protecting various parts of buildings from the action of fire.

Mr. Farrow, of Great Tower-street, London, took out a patent a few years since for a new method of constructing fire-proof buildings, a large model of which was erected in Mark-lane, for public inspection. The walls are of coarse brick or stone, built in the usual manner. The joists are of wrought iron; they are formed with a lateral projecting flange on each side, upon which are laid, from joist to joist, a series of flat stones, and of sufficient thickness (from two to two and a half inches,) to lie flush with the upper edge of the joist, forming a level floor of stone interlined with iron: it may be used in this state, or covered with planks, according to the purposes of the apartment. The ends of the joists are turned down and let into bond stone laid upon the walls, and cemented or run in with lead, which, with the weight of the walls, continued upward, takes off the elasticity of the iron, so as to enable the joists to carry almost any weight, and at the same time ties the walls together in such a manner as to render it impossible for them to separate. The boarded floors are grooved into the edge of the joists about half an inch, and when dowelled, will require very little fastening down. But where it is necessary, a stub is let into the stone floor, and screwed to the edge of the board; there are, therefore,

no nails necessary, nor any other fastenings visible when the floors are finished. The under part of the stone is stabbed or made rough, so as to form a good key for the ceiling, therefore no laths are necessary, and the whole floor occupies no more than from four to five inches in depth. A roof is the same; and, being covered with mastic, is, according to the statement of the patentee, the cheapest roof ever invented, with the important advantages of being fire, air, and water-proof. These floors have been successfully employed in some sugar refineries, and other premises liable to accident from fire, and are admirably adapted to prevent this calamity. Having thus briefly described some of the most important facts relative to floors, we proceed to state that the most material part of all buildings, so far as prevention of fire is concerned, is the staircase,—for this part, above all others, acts as a conductor, and greatly assists the spreading of the flames. When a fire is discovered before it has gained possession of the stairs, its suppression is comparatively easy; but the staircase once on fire, there is but slight chance of saving the building. Effectually to prevent the spread of fire, therefore, it is absolutely necessary that the stairs should be wholly composed of some incombustible substance. In many places on the continent the stairs are always of stone, which is quite sufficient to account for the speedy manner in which conflagrations are extinguished by the fire associations of those countries, where, although the number of fires are considerable, the amount of damage is usually very small. Nothing gives a more elegant appearance to a house than a clean well-proportioned stone staircase, and this material is by far the most eligible for the purpose; economy, however, may dictate the employment of a cheaper material without prejudice to the effect. In ordinary dwelling houses it is necessary that the roof should be as light as practicable, nor is it very essential to bestow fire-proof qualities on this part; but in manufactories and public edifices it becomes desirable to render the building fire-proof throughout. This is done in some cases by using cast-iron framed roofs, with metallic or other covering. At the New Palace, in St. James's-park, the builder, Mr. John Richardson, of Spencer-street, introduced fire-proof floors and roofs, composed of hollow earthen coombs or pots, invented some thirty years before, and first used at Knight's Hill, near Dulwich, the seat of Lord Thurlow. The coombs are arranged in arches, springing from stone abutments resting on the flanges of the iron girders; the spandrils of the arches are filled up with brick work, forming a level roof, which is covered with hot cement. This cement is composed of chalk, coal tar, and sand. The first coat being levelled with heated irons, is suffered to harden; a second coat is then applied, and the slates embedded in the cement while it is hot. Woeful experience has shown that the defective construction of chimneys and setting of stoves have been a fruitful source of fires; a slight attention to these points would be sufficient to remedy the evils arising from this cause. Lateral openings are sometimes imprudently suffered to remain, communicating between the chimney and sides of the room; these places in time become filled with soot, which a falling spark ignites, and sets fire to the apartment. No beam should on any account be permitted to enter a chimney; this was too common formerly, and has caused the destruction of many buildings. An act of parliament, passed some years back, for regulating buildings, and so preventing the spread of fires, has tended in some degree to remedy the evils just referred to; this act, however, contains many incongruities, and it stands greatly in need of that revision which it is expected very soon to undergo. It would doubtless be both useful and interesting to follow out the subject of fire prevention, and detail the cautions necessary to be observed in the application of fire-heat to manufacturing processes, as well as the management of fire and light in the arrangements of domestic economy. The limits of this work, however, will not permit us to extend the present article; but in many of those that follow we shall have occasion to make some observations on the subject.

FIRE-PLACE is a general term given to the brick, stone, and iron-work, which constitute the apparatus for heating the apartments of dwelling-houses, and for performing culinary and other domestic operations, to which the various names of stoves, stove-grate, grate, and range, are given; but as it would be

uninteresting and useless to explain, in this place, the *bath*, *pantheon*, *rumford*, and other common open stoves and ranges, with which every eye is familiarized, we shall confine our notice to the leading features, (stripped of all ornament), of those deviations from the ordinary apparatus, which are regarded as improvements upon the before-mentioned. It has been remarked, that Englishmen, who boast so much of their firesides, and who are the greatest and most skilful manufacturers of iron work in the world, are generally the worst provided with the means of comfortable warmth of any civilized nation. The mode almost universally adopted for increasing the temperature of our apartments by the common open stoves, supplied, as they are, with air drawn from around the chilled persons of its occupants, is perhaps as wasteful and inefficient as could be designed. Full nine-tenths of the heat generated in the grate is rapidly conducted away up the chimney into the atmosphere, while the remaining feeble tenth is radiated into the apartment. The introduction of the *register* stoves, about thirty years ago, undoubtedly effected a considerable mitigation of the evil just mentioned. These stoves, filling up the entire opening of the fire place, and being provided with a flap door at the upper part of the back, which can be opened and shut, more or less, according to the state of the fire, and the emission of the smoke, check in some degree the current of cold air which is constantly rushing to the fire-place to fill up the vacuum in the chimney, and support the combustion of the fuel in the grate. When there is only a little, or a very clear fire in the grate, the flap door may be almost closed, in which state it prevents the falling of soot into the apartment. There is, however, this objection to such stoves being made entirely of metal, which, from its great conductibility, is not so economical with respect to the fuel as the following, and some others of a very humble kind.

Irish Stove.—Mr. Buchanan, in his *Essay on the Economy of Fuel*, relates, that on landing in Ireland, he was much struck with the excellent construction of the fire-grate in the room of the inn where he lodged. He at first thought it was an invention of his landlord's, but on proceeding on his journey, he found the same kind of grates common in that part of Ireland. *Fig.* 1 represents a front elevation, and *Fig.* 2 a transverse vertical section of one of these fire-places, which appear well calculated to remedy the smoking of chimneys,

Fig. 1.

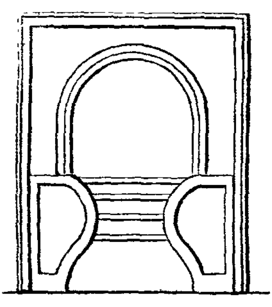
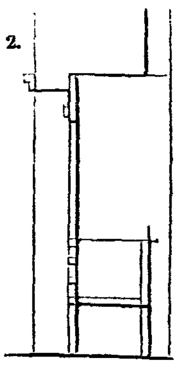


Fig. 2.



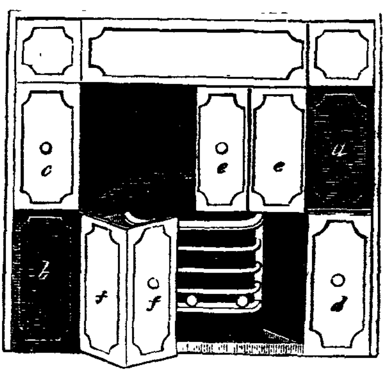
and, at the same time, to lessen the consumption of fuel. The fire room is wide and shallow, presenting the greater surface of fire to the room, and thereby radiating the greatest quantity of heat into it. The upper portion of the chimney recess is partly closed by an upright slab of fire stone, in which is cut an arch. The back wall is formed of fire stone, or fire brick, into an oval niche, and the throat of the chimney is made very small to increase the velocity of the air, and thus enable it the better to carry off the smoke.

Birmingham Stove.—The stoves in common use in Staffordshire and Warwickshire, although not so elegant as those made in London and Nottingham

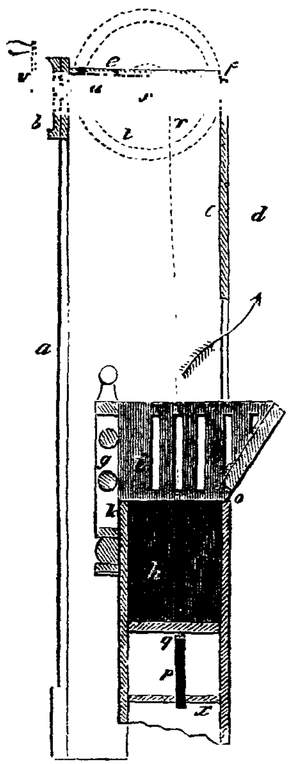
for the same class of rooms, are far more judiciously disposed for diffusing warmth. Instead of the usual recess in the brickwork for the reception of the stove, the wall is built up in front from the ground to the mantel, and flush with it, leaving only an aperture of eight or nine inches square for the passage of smoke into the chimney; this is situated just above the back of the stove, which is placed against this wall, projecting its whole depth entirely into the room.

Open Fires.—There is, from long custom, so great a desire among all ranks in England to see the fire that warms their apartments, that the most convenient, cleanest, and cheapest methods of heating them, are sacrificed to this single circumstance. Accordingly, persons who attempt the improvement of stoves are compelled to endeavour to combine what appears to be irreconcilable, namely, the appearance of a bright open fire, with an economy of fuel, regularity of temperature, and without producing a draught through the apartment. Of the various contrivances in which the attainment of these properties have been attempted, there are but few worthy of notice.

Sir George O. Paul's Stove.—This stove may, at pleasure, be made either an open fire-place, or a close stove, heating the room by the radiation of the heat from its front wall; and when thus acting as a close stove, it serves as a ventilator of the apartments with which it is connected. The fire-place is of the ordinary dimensions. Folding doors are made to close the fronts of the ash-pit, and to fall back against the hobs; other folding doors are made to close the front of the grate, and to fall back against the sides. The top of the fire grate was also provided with a floor, which formed a back when open, but when shut down horizontally, left only a small cavity, and produced a strong draught. It was supplied with air by tunnels underneath the hobs. Although the utility of this stove was satisfactorily proved in Gloucester gaol, and other places, its clumsy inelegant appearance prevented an extensive adoption. Mr. Marriott has, however, so modified it as to remove the above-mentioned objection, and has recently brought it before the public in the following form. The shadowed compartments *a* and *b* are recesses just of sufficient depth to admit of the doors *e e* and *f f*, when folded back, to lie flush with the other parts of the front of the stove, as is the case with those marked *c* and *d*. We have thus arranged them in the drawing merely to render the matter quite clear to the eye, not that such positions of the doors are peculiarly eligible, (nevertheless cases may be imagined wherein they would be so, such as screening particular objects from the influence of the fire, or increasing the combustion of a particular part of the fuel, by altering the direction of the current of air.) In lighting a fire, or in replenishing one that is low, the combustion is greatly excited by shutting the *four upper* doors, which act as a "blower." On the contrary, when a fire burns too rapidly, or is not much wanted, the *four* lower doors may be shut, which will damp it immediately, yet allow a great portion of the heat to radiate into the room. On retiring to bed, or wishing to leave the room in perfect security from fire, all the doors may be closed, when the fire will infallibly go out for want of draught. To keep in the fire, and yet leave the room in safety, or to prevent the radiation of much heat and light in a room (often desirable in the chamber of the sick), the doors may be placed thus ¯V V¯. For such chimneys as occasionally return their smoke, or in which the draught is feeble, these stoves will, we doubt not, be also found very convenient and advantageous.



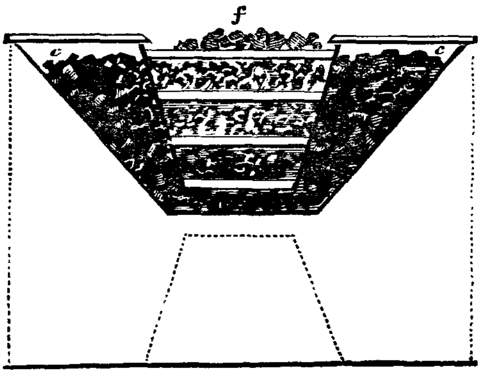
Pycroft's Patent Fire Stove.—Mr. Pycroft, of Rolleston, near Burton-upon-Trent, took out a patent for improvements in fire-places, in 1831, the principle of which consists in connecting with the fire stove a chamber for hot air, to be admitted at pleasure either into the apartment where the fire is situated, or into one adjoining thereto. The hot-air chamber extends from below, up behind, and on each side, and over the top, under the mantel. The air passes into the chamber by a series of registers situated below the fire, and when heated, passes out into the chamber by a series of registers situated over the fire. When it is intended, for the sake of ventilation, to receive the air to be heated from the external atmosphere, instead of from the room where the fire is situated, the registers below the fire must be closed, and a communication opened between the external air and the lower part of the chamber; and when it is intended to throw heated air into an adjoining apartment above the fire, the registers are to be closed, and a communication opened between the upper part of the chamber and the apartment to be heated. For the purpose of exciting a draught at pleasure, and of preventing any smoke issuing into the room, a hood or blower is hinged to the upper part of the grate, which may be brought out towards the front or top bar of the fire. Behind this is another hood or blower, which is raised or lowered by a knob passing through the first; this inner hood is provided with angular side-flaps, which, when the blower is brought down and projected forwards, inclose the side of the fire. This stove has likewise a flap valve at the back, acted upon by a handle in front, by which the flue or throat into the chimney may be regulated in its dimensions, and the draught increased, diminished, or entirely stopped at pleasure.



Cutler's Patent Stoves.—This invention, when first brought before the public in 1815, met with considerable patronage; but it is now, we believe, but little used, owing to some difficulties of a slight description, for which no sufficient remedy has yet been provided. The spirit of enterprise which originated the invention received, we have been informed, a severe check, by the numerous and combined attempts of rival manufacturers to invade and destroy the patent right, which is now expired. The principle of the contrivance is, however good, and will probably, under able management, become a valuable apparatus. The invention consists in the construction of stoves and fire-places in such a manner as that the fuel necessary for combustion shall be raised and supplied from a close chamber beneath, where the upper stratum of coal shall be constantly undergoing the process of coking, the gas from which becomes ignited in passing through the open part of the grate above, and by causing the said chamber to descend at pleasure, so as to extinguish the fire. The figure represents a vertical section of a register stove, presenting an end or side view; *a* is one of the front pilasters; *b* the entablature; *c* the back; *d* the chimney, the entrance to which is shown by the curved arrow; *e* the top plate, turning upon hinge joints, to be raised up whenever required for sweeping; this top does not fill up the space accurately, but leaves a narrow opening at *f*, for the escape of the vapour and dust that may arise prior to the current being established in the direction of the arrow, by the effects of the combustion; *g* are the front grate

bars; *h* the receptacle of the coals, including *i*, the place (as usual) where they are burned. As the air which finds its way into the close box *h*, is only sufficient to coke the coals, their perfect combustion is not effected until they are raised above the front plate *k*, at which place the air pours in on all four sides, between the bars in front, through the side grates, one of which is shown at *l*, and from an aperture at *o*, under the bottom edge of the back; *p* is a vertical groove, in which the bar *q* (seen endways) traverses up and down, supporting the movable bottom plate of the coal box *h*. To each end of this bar, exteriorly, is attached a chain *r*, which thereby suspends the coal chamber (or movable bottom), by an horizontal roller *s*, extending across the stove. This roller is the shaft or axis of a cog-wheel *t*, and is put in motion by a pinion *u*; the axis of *u* is a small square pin, fitting into the cavity of the winch *v*; the turning round of the latter winds the chain upon the roller, and elevates the movable bottom *q*, which raises the coals, as they may be required for combustion, to supply the place of those which have been consumed. On turning the winch the contrary way, the bottom of the coal receptacle descends by its own gravity, and that of the coals resting on it, as far as the plate *x*, when the fire dies away for want of air. The patentee employs a pall and ratchet to stop the action of the roller, which is operated upon by pressing upon a pin, placed externally. Two objections have been urged against these stoves; one, that the current of air passing through it makes an unpleasant roaring noise, like that of an air furnace; the other, that the expansion of the coals in undergoing the process of coking prior to being raised into the open part of the fire, causes them to adhere so fast to the sides, as to render the friction excessive, and the labour great, of raising up and getting down the coals. These objections are, however, we believe, not of an insuperable character, and may be overcome by mechanical skill.

Mrs. Smith's Stove.—A plan of a stove designed for burning its own smoke, was communicated by Mrs. Rachel Smith to a periodical journal, which seems susceptible, by its simplicity of construction and soundness of principle, to be made effective for the object intended The stove is made exteriorly of the usual form, excepting that the fire part *f* is of greater length or height than is



common, and the spaces under the hobs are made into reservoirs to receive the coals, as shown at *c c*, for supplying the fire. The hobs are upon hinges, and form lids, which shut down very closely,—if air tight, the better. The cheeks of the grate are open at the bottom, so that the coals lying upon the inclined planes of the reservoirs descend by their own weight, and occupy the lower part of the grate; and as the fuel is consumed, or raised by the poker, a fresh portion of coals enters from either or both of the reservoirs, and fills up the space. In this manner the fuel is constantly supplied, occasioning little or no smoke. The reservoirs should be of a capacity sufficient to hold enough coals for the day's consumption.

Atkins's Patent Stove.—Messrs. Atkins and Marriott had a joint patent for a smoke-consuming stove on the principle of the last described, which they manufactured in a style of great elegance, and adapted to the various situations and applications of domestic stoves. The patentees state their objects to be, first, to afford a remedy for smoky chimneys; and secondly, to economize fuel, and regulate the heat evolved from stoves or grates for warming apartments, and for the various operations of cooking. In order to effect the combustion of the smoke, the coals are thrown into a coal chamber at the back of the grate, which is closed by a door. At the lower part of this chamber there is an opening through the back into the grate, the interior of the box being formed so as to throw the coals forward to supply the grate when necessary. The other improvement made by the patentees consists of an appendage, in lieu of a fender, attached to the front and lower part of any kind of stove or grate, which they denominate a basement. This basement they usually make of a convenient inclination, to put the feet upon, but it may be made of any figure or dimensions according to individual taste. It is provided with a drawer or box to receive the ashes, beneath the fire, and with apertures in front to admit air beneath the fire bars. The whole of the interior of this basement, except the ash box, is filled with a mixture of pulverized charcoal and lime; the stove has also a canopy or cornice filled with similar slow conductors of heat; also each side of the grate, as well as a part of the back, are provided in like manner. The effect of these appendages, in retaining that portion of heat which is nearly all lost to the apartment in other stoves, is doubtless very great; we are, indeed, credibly informed that it will preserve nearly the same temperature in a room for several hours after the fire is extinguished. These stoves have pipes or passages for allowing a column of air to ascend through the basement and upper portion, which becomes warmed in its passage, and flows out into the apartment above.

Jacomb's Patent Grates.—The principle of this invention also consists in placing the fresh fuel underneath the ignited portion; but the mode of carrying it into effect is peculiar. The stove is a kind of grated cage, cylindrical or parallelopipedal, turning upon axes, which are mounted on side standards. On two of the opposite sides of the said cage is a grated door, each of them serving alternately for admitting the fresh fuel, and as an ash grate. The coals are supplied at the top of the fire; the door of admission is then shut, and the grate turned half round, so as to bring the fresh fuel underneath, by which means the gas emitted becomes inflamed in its ascent through the ignited fuel above. The selection of the materials, and the diversification of designs and proportions for the construction of stoves, will of course depend upon the uses to which they are applied; but we will select, as an example, the following one adapted for a parlour. *Fig.* 1 is a front view, and *Fig.* 2 is a side view. *a a*

Fig. 1.

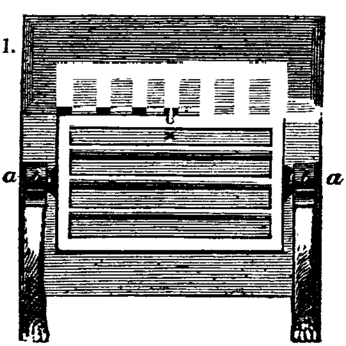
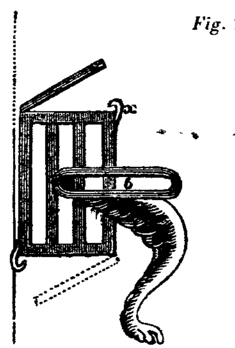


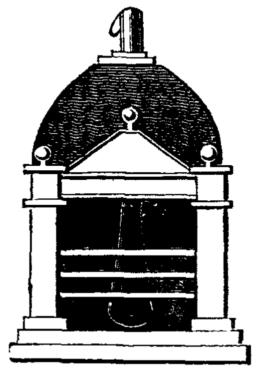
Fig. 2.



are the axes, which rest and slide in horizontal grooves *b*. The two doors before mentioned, represented in *Fig.* 5, are made fast by catches *x x*. The stove is put into action by lighting a fire in the ordinary manner with coal or

other fuel, as near as possible at the top, preferring to place uppermost the cinders, and green coal undermost; the fire will then gradually find its way to the bottom, burning with little or no smoke, which, together with the gas or vapour, is consumed as emitted. When fresh fuel is required, it is to be placed on the top of the ignited fuel, and the door shut down and secured by the catch *x;* the grate is then to be drawn forward in the groove *b*, and turned round one half of a revolution on its axis, and then be returned back again to its former position in the groove.

Lloyd's Patent Stove consists in the adaptation of a box in a recess at the back of an ordinary register or other stove, for the reception of sufficient coals for a day's consumption, which are to be drawn forward into the fire as they may be wanted, and thus supersede the use of the coal scuttle,—an utensil which has certainly its inconveniences. That this operation may be performed with facility, the box at the back of the stove is closed with a sliding door, the weight of which is supported by a counterbalance suspended over a pulley; it is therefore drawn up or let down with ease, by means of a small handle placed conveniently, when the coals may be raked on to the fire by means of the poker.



Smoke-consuming Stove.—The annexed cut is illustrative of a design, by an anonymous inventor, for a stove to consume its own smoke. We are not aware of its having ever been constructed, but as it presents a novel and elegant arrangement of parts, calculated to answer the intended purpose in judicious hands, we give it insertion. The inventor proposes that the smoke from the fresh fuel shall be allowed to ascend up a short flue, and then descend and rise again through a tube placed in the middle of the fire, after which the tube conducts the remaining incombustible gases into the chimney. The intense heat of the tube which rises through the fire must necessarily burn the smoke, economize fuel, and increase the temperature of the room.

Silvester's Patent Stove.—The common methods of heating buildings by means of hot air stoves had been much and justly complained of, from the salubrity of the air being frequently injured by its coming in contact with the surface of a stove comparatively small, but intensely heated; and to remedy this evil, the late Mr. Silvester introduced cockle stoves, first in the Infirmary of Derby, and afterwards in many other places, with large heating surfaces, that they might be sufficient to heat moderately a large quantity of air, but not to be heated so high as to injure any portion of it; and thus was obtained an extensive ventilation by air moderately warmed. (See Air.) Still, however, stoves of this kind, without considerable care and skill on the part of the firemen, were liable to become over-heated, and at times to deteriorate the air; and to obviate the possibility of this defect seems to be a principal object with the present patentee. He proposes, in the first place, to lower the fire grate, till the bottom bars are on a level with the surface of the floor of the room in which it is placed. The fire bars are prolonged and widened to touch each other in front of the fire, so as to form a hearth. They require no fastening into their places, but simply to be laid upon appropriate bearings at each end. There are grooves made on the under sides of the fire bars, for the admission of fresh air for supporting the combustion of the fuel within the grate, and for the escape of hot air into the room. It is stated that the bars may be either made of equal lengths, to constitute a rectilineal hearth, or of different lengths, to constitute a curvilineal one, at pleasure. When the ash pit, which is situated below the fire in the usual manner, requires clearing out, a few of the fire bars are to be removed, which can be effected with facility, as they are not made fast to any thing. Mr. Silvester proposes, in the second place, to surround at least three sides of his fire with a vessel containing water, and upon the exterior of this

water vessel he causes a large quantity of cold air to impinge, that its temperature may be elevated sufficiently to communicate the required degree of heat or ventilation to any adjacent apartments to which it may be conveyed. For the purpose of conveying the cold air to, and the heated air from, the water vessel, the patentee proposes to employ apparatus of the same description as that employed with the hot air cockles invented by his father.

Gaunt and Eckstein's Grate.—The stove designed by these gentlemen (for which they had a patent in 1831,) has a grate of bars, of a semi-elliptical form, attached to a straight back, which is brought much further forward than are the backs of stoves of the usual construction, by which arrangement three sides, or what is equivalent to three sides, of the fire, is in a situation to radiate heat into the room. Immediately over the fire is placed a metallic hood, which receives and radiates into the room a portion of the heat which would otherwise pass up the chimney. The distance between the fire and hood is diminished and increased at pleasure, by elevating or depressing the grate containing the fire, and thus is obtained the means of increasing or diminishing at pleasure the draft of the fire, and of preventing the escape of smoke into the room. The change in the altitude of the grate is effected by means of projections from the grate passing through vertical slits in the back, which projections are joined together by a cross bar, attached to a lever by a connecting link; this lever has on its exterior end a toothed sector, which is actuated by a small pinion, whose axis receives a regulating winch, passing through a small hole in the back. This hole, with the pinion axis, is the only part connected with the rising apparatus which is visible in front, which admits of their being manufactured in a style of great elegance and neatness.

Maw's Stove.—This apparatus, for which Lieut. Maw obtained a patent in 1831, consists in the introduction of a fuel drawer, or receptacle for the fuel, which is placed under a grate of the usual construction, in order that the most volatile portion of the fuel may be liberated and be consumed in its ascent through the fire; and when the coal has thus, by parting with its gaseous matter, been converted into coke, it is to be removed from the fuel receptacle, and placed upon the fire, leaving the receptacle at liberty for the introduction of another supply of fresh fuel. A front elevation of one of Lieut. Maw's fire grates is

Fig. 1.

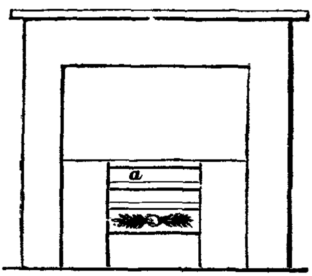
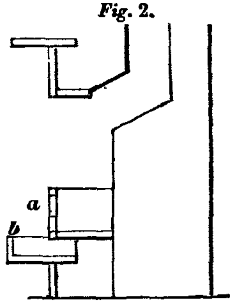


Fig. 2.



exhibited in the above cut at *Fig.* 1, and a sectional side view, *Fig.* 2, wherein *a* shows a grate of the usual construction, and *b* a fuel drawer or receptacle, having a grating underneath, for the admission of atmospheric air to maintain the combustion. The openings in the grating between the fire and the fuel receptacle are made at some distance from the front, that the volatile matter, in its ascent, may not pass so near the front of the fire as to be cooled, lest it escape without being consumed. The advantages which would result from having the fuel supplied to a fire under the ignited portion, have been long acknowledged; and of the various plans that have been proposed, we do not think there is one so well calculated to answer the purpose of burning the smoke as that of Lieut. Maw.

Witty's Fire Places.—Mr. Witty, by a judicious attention to proportions,

and the conveniences required, has succeeded in adapting the original invention of Watt (described under the word FURNACE,) to domestic stoves, particularly those of the close kind. Mr. Witty has, however, unadvisedly taken out a patent for these stoves, although we can discover nothing that is original in the principle nor in the arrangement of the parts. Some elegant and very effective stoves on this plan may be seen at the Museum of National Manufactures and the Mechanic Arts, in Leicester-square.

Nott's Patent Furnaces.—A very effective kind of close stove, particularly adapted to large rooms, halls, and churches, and possessing considerable novelty of appearance, has lately been introduced into this country by Mr. J. B. Nott, from the United States. In the upper part of a low pedestal is a large capacious chamber, capable of holding a sufficient supply of coals for the day's consumption; from this receptacle the coals gradually sink down, as they are consumed, in front of the grate, and are deposited upon an arched grating, supported upon a pivot, upon which it is made to oscillate, (by using the poker as a lever for that purpose,) and thereby clear the bars of ashes; and when it may be necessary to clear or put out the fire entirely, the said vibrating grating is moved through a greater angle, by which all the ignited fuel thereon is thrown out at either end of the arch. To give the lively appearance of an open fire, and the security of a close stove, the front of the stove is enclosed by windows of talc, through which the glowing fuel is seen. The air is admitted for lighting the fire by leaving the ash-pit drawer a little way open, and when ignition is complete, the drawer may be entirely shut, as sufficient air finds its way through the imperfect junctions or fittings of the metal, to preserve a vivid combustion of the fuel. The fire chamber is encased in fire brick, or some other suitable slow conductor, which prevents the surrounding cast iron from obtaining that high temperature which is found to deteriorate the air of the apartment, and the heat is in consequence more uniformly diffused over the other parts of the structure, which presents altogether a very extensive surface of metal for the radiation of heat, principally derived from a tall ornamented chimney, of a flat pyramidal or pilaster-like form. In this chimney there is a turn valve, to regulate the egress of air, the action of which, together with the management of the ingress crevice at the ash-pit drawer, determines the quantity of heat or the rate of combustion of the fuel. In fitting a stove of this kind to a room having the ordinary cavity for the fire-place, Mr. Nott converts the latter into a hot air chamber, and places his close stove upon the hearth in front. A stove of this kind is employed for warming the extensive range of rooms at the Museum of National Manufactures and the Mechanic Arts, in Leicester-square, which it does most efficiently, with very great economy of fuel. Anthracite, or stone coal, which is almost wholly free from bituminous matter, and emits, in consequence, scarcely any smoke, may be very advantageously burned in stoves of this kind.

German, Pyramidal, Pedestal, Sarcophagus, &c. Stoves.—All grates of this class are, strictly speaking, close stoves, the fire being entirely shut up within them, the flue or chimney usually consisting of a metallic pipe, which is conducted through the walls of the room to the external atmosphere. The German stove is a vertical cylinder of sheet iron, mounted upon legs, having internally, and about midway, a short cylinder of cast iron, with a grating at bottom, which constitutes the fire room, and underneath is the ash pit. The tops, which are variously formed to suit particular purposes, are made to take on and off, so as to allow of baths, boilers, or retorts, to fill up the aperture, and thus become the cover to the upper part of the furnace; the application of heat is thus very convenient and effective, and is much used for chemical processes, and manufacturing operations on the small scale. The pyramidal, pedestal, and sarcophagus stoves are of similar internal construction to the German or cylinder stoves, but they are usually of cast iron, and designed with a view to ornament as well as utility: their external forms are explained by their names.

Having now described the principal varieties of stove grates or fire-places in their most improved forms, (including air stoves, which will be found under the article AIR), we shall close this part of the subject by a few observations on the

proper construction of fire-places in general, in order that the reader may understand the defects that may exist in his own, and know how to apply the remedy. In open fires the bars should not be larger than is necessary for strength, as they obstruct the radiation of heat, and prevent the egress of air, which is requisite for making the fire burn clear. To attain a clear fire, Mr. Tredgold justly says, that the sides of the burning fuel should be at least half surrounded with slow conductors of heat, otherwise the heat developed will pass off so quickly by conduction, that the fuel will burn dead, and that heat which ought to be radiated will be expended in warming the walls, &c. behind the fire. Iron is a very rapid conductor of heat, and therefore it should be used as sparingly as possible. Fire brick, a slow conductor, is employed with much advantage for the backs and ends of grates by a few manufacturers, but iron-mongers in general seem to think it more desirable to use iron than to economize fuel, or to work on sound principles. But when a fire-place, made of slow conducting materials, is large and filled with fuel, as soon as the fire becomes bright the heat is extremely intense and scorching; when the fire is in this state it is often too powerful for the room, though perhaps barely sufficient when the combustion is less perfect. This may be remedied by any method which enables us to expose a greater surface of hot matter with the same bulk of fuel, and at a lower degree of heat. Some time ago "fire balls," (spheres made of baked clay,) were used with this object; but their inconvenience, when not judiciously attended to, brought them into disrepute. An improved substitute for them has been suggested by Mr. Tredgold, when the fire is of greater length than 18 inches; that of building a projection from the back of the grate (and of the same depth) to within three inches of the front bars. This projection should be of good fire brick, and built firmly in with the other part of the back. Thus is left a space for a sufficient body of fire on each side, and the surface is increased without adding to the mass of burning fuel. The combustion of the fuel in an open grate should not be faster than is necessary to produce a clear fire. To guard against the loss of heat by the warm air of the room ascending the chimney, two partial remedies have been adopted—that of lowering the mantel, and contracting the throat of the chimney; but the first of these remedies impairs the ventilation of the room, and the second, causing a rapid draught, increases the consumption of fuel. For some rules in duly proportioning the flues, see the article Chimney. A grate should offer as little obstruction as possible to the radiation of heat, and therefore the usual mass of metal below the front bars, called a fret, is objectionable; and the sectional form of bars should be that of a wedge, with the sharp extremity rounded off, which part should be inside, or next to the fuel, as it is advantageous to have as little metal as possible in contact with the fuel. There is, however, no objection to the employment of metallic covings, as reflectors of heat, when separated by a slow conductor from the metal of the grate; and instead of these being blackened, as they are usually in the common Rumford stoves, they should be bright or polished surfaces, and preferably of brass to the other common metals. The angle best suited for the covings is 45° with the front line of the grate. The height of the grate from the floor is an object of some importance; if it be placed too low, the heat is expended almost wholly on the hearth, and the fire-place seems buried within the fender; if it be placed too high, a person's face is scorched, while too small a portion of heat is given to the floor to render a room comfortable; but a high mantel has the advantage of producing a more effectual ventilation. Mr. Tredgold considered that the top bar of stoves ought not to be less than 20 inches from the floor, and never exceed 2 feet; and when the lower part of the fire is not buried in a mass of metal work, there will be an abundant supply of heat thrown upon the floor from the greater height. The space between the top bar and the mantel will require to be proportioned to the size of the room and the height of the chimney, and in ordinary cases may be about 15 or 16 inches. With respect to the proportion of grates to different sized rooms, Mr. Tredgold has, from observation, deduced the following rule:—Let the length of the front of the grate be made one inch for each foot in length of the room, and the

depth of the front be half an inch for each foot in breadth of the room. If the length of the room be such as requires the grate to be longer than 2½ feet, two fire-places will be necessary; and in that case the same proportions may be adopted, divided into two grates, unless the room be very wide, when a greater length should be given, and less depth, so as to preserve an equivalent area. For various information connected with this subject, see the articles VENTILATION, COMBUSTION, AIR, FURNACES, &c.

Welles's Patent Peripurist.—This is a small portable cooking stove, and is very ingeniously contrived. The patentee states in his prospectus of it, that "it boils water, prepares coffee and chocolate in a very superior manner, boils eggs, cooks a beef-steak or a slice of ham, all in less than ten minutes. For dinner, it will prepare soup, steam vegetables, and cook fish, chops, or steaks, at the same time; and for these one farthing's worth of fuel is sufficient." *Fig.* 1 is an external view, and *Fig.* 2 is a vertical section; *a* is a small cone of cast iron, having at the bottom a grating, on which is put the fuel (charcoal), broken into small pieces; below this is a small chamber *b*, perforated at its sides for the admission of air, and containing a small pan to receive the ashes, and also to light the charcoal by a piece of paper; the vessel *c* contains water, which entirely surrounds the cone; the next vessel *e* above is intended to be

Fig. 1.

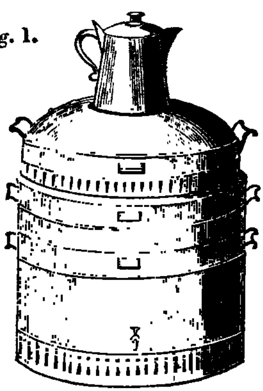
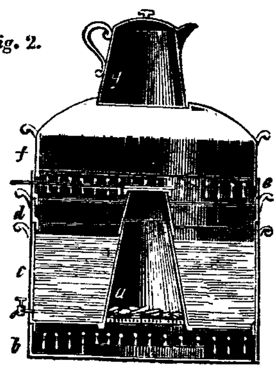


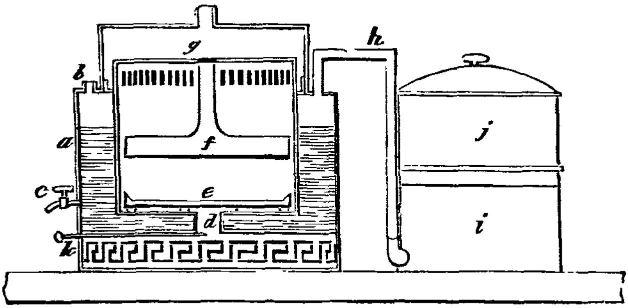
Fig. 2.



used as a steamer; it has in its centre a frustrum of a cone, the lower edges of which descend below the bottom of the vessels, and fit upon the cone beneath, so as to carry up the flue to the chamber above, which has open perforated sides, whence the vapours produced by the combustion escape. On the top of the cone there is a valve for enlarging or diminishing the aperture, having a horizontal rod fixed to it, which passes to the outside of the vessel, as shown. The vessel over this, *f*, is, we suppose, a stew-pan, or something of the kind; it is heated by the hot air and direct influence of the fire; above this pan is placed in a cavity of the cover a small pot for warming small quantities of liquid. There are several appendages or vessels for peculiar purposes, such as the boiling of eggs, &c. which fit one over another in a similar manner to those described. The apparatus is proposed to be used on the breakfast or dining-table, to be taken in a carriage, in a boat, or carried by pedestrians.

Tozer's Patent Calefactor.—This is another ingeniously contrived little cooking stove, and is intended to meet many of the wants of a small family, especially in the summer season, when the smallest quantity of artificial heat is desirable. The diagram in the next page is explanatory of its construction and arrangement when applied to roasting and steaming; some of the parts in the drawing are slightly varied from their real positions, for the purpose of elucidation by a single figure. *a* is the steam boiler, which has a large elliptical opening down the centre for depositing a variety of culinary vessels

therein; *b* an aperture for charging the boiler with water; *c* a stop-cock for drawing off the water as may be required, but placed high in the boiler to admit a draught of air to the grating *e*, on which the charcoal is burned;—the grating is, strictly speaking, a strong iron plate, perforated all over for the free



admission of air through the holes; *f* is termed the *oven pan*, which is a cast-iron dish, suspended about half way down the elliptical opening; *g* a sheet-iron cover; *h* a pipe conveying the steam from the boiler *a* to the steamers *i* and *j*, which separate in the middle, and allow of one or both being used at a time; each of these steamers may be subdivided into distinct compartments; *k*, a sliding damper for enlarging or contracting the air passage *d*, so as to increase or diminish the combustion of the fuel, as may best suit the peculiar culinary process. When the *apparatus* is not required for roasting, but for boiling, or making soup or broth, the oven pan is to be removed, and in its place the required vessels (all of which are made to fit) are deposited. In some cases the patentee adopts two half-kettles instead of one. A current of heated air is constantly kept up, entering at the grating at bottom, and passing out at the grating above, where the heat is reverberated against the top and sides of the cover, prior to its escape through a small central aperture in the latter.

FIRE-SHIP. A small vessel filled with combustible matter, and employed for the destruction of an enemy's shipping by being run into the midst of them, and set on fire by the crew before they quit the vessel.

FIRE-STONE. A coarse kind of free-stone, obtained at Reigate and other places, which is capable of bearing a considerable degree of heat, and is therefore used in the construction of furnaces, ovens, &c. Its colour is a pale grey, tinged with green, which the fire changes to a light red.

FIRE-WORKS. As the leading object of this work is utility and not mere amusement, we shall but very briefly notice the nature and composition of artificial fire-works. Of these the most generally interesting, from the great altitude of their flight, are rockets. They are made by ramming into strong cylindrical paper cases (put into wooden moulds to support them) powdered gunpowder, or the ingredients of which it is composed; namely, saltpetre, sulphur, and charcoal, very dry. To represent a fiery rain falling from the rocket, mix among your charge a composition of powdered glass, filings of iron, and sawdust; this shower is called the peacock's tail, on account of the various colours exhibited. Camphor mixed with the charge produces white or pale fire; resin, a reddish colour; sulphur, a blue; sal ammoniac, a green; antimony, a reddish yellow; ivory shavings, a silvery white; pitch, a deep or dark coloured fire; and steel filings, beautiful corruscations and sparks. Sticks are fastened to the rockets for the convenience of discharging them, and causing them to pass through the air like an arrow; the resistance of the air to the rush of fire at the end of the rocket causing it to ascend. Artificial fire-works differ from each other very much in point of simplicity of construction. Some require very little dexterity in the preparation, and are either employed as

appendages to works of greater importance, or, if used by themselves, are confined to the sports of school-boys. Of this nature are squibs, crackers, serpents, stars, sparks, maroons, saucissons, pin-wheels, leaders, Roman candles, &c. Others are very complex in their structure, require considerable address and ingenuity, and form the amusement of fashionable circles on occasions of public rejoicing, or private festivity: such are wheels, suns, globes, pyramids, &c., and rockets of various kinds. Those who wish for precise instructions in the preparation of these resplendent trifles, we would recommend to consult the article PYROTECHNY, in the *Oxford Encyclopedia.*

FLAGEOLET. A little flute, made of box or other hard wood, with an ivory mouth-piece, and having six holes besides the one at bottom, and one behind the neck. Great improvements were made in this pleasing instrument by the late Mr. Bainbridge, who also invented the double flageolet, upon which one person may play duets.

FLAIL. An instrument for threshing corn. It is composed of two staffs united at one end of each by strong double leathers.

FLAME. The luminous phenomenon produced by the combustion of gaseous substances, or under certain circumstances of a solid and a gaseous body.

FLANNEL. A kind of loose woollen stuff, composed of a woof and warp, woven in a loom with two treddles, in the manner of baize.

FLAX. A plant having a slender, round, hollow stalk, about two feet high; its bark is full of filaments, like hemp; the leaves are long, narrow, and pointed; it bears a blue flower, to which succeeds a roundish fruit, about the size of a pea, containing ten little seeds, full of an oily substance, or meal. There are twenty-five species, of which the most remarkable are the common annual flax, and the perennial Siberian flax.

FLAX DRESSING. Before flax can be converted into cloth or other articles, it undergoes certain preparatory processes, constituting what is called "dressing;" the object of which is to separate the boon, or core, from the flax, which is the cuticle, or bark of the plant, and to straighten out the fibres for the spinner. These operations are sometimes performed by hand, but at the present day more commonly by machinery, driven by steam or water power. When the flax is dressed by hand, the bark is separated from the core by means of an instrument called a "flax-brake," composed of three wooden teeth or swords, fastened longitudinally on a horizontal bench, and of a lever, to the under side of which are fixed similar, but rather smaller teeth, which fit in between the interstices of the others. The flax being held in the left hand across the under swords of the brake, the upper teeth are then with the right hand quickly and often forced down upon the flax, which is artfully shifted and turned with the left hand, in order that it may be fully and completely broken in its whole length. The fibres are then straightened by means of a kind of comb called a "hackle," whence the operation is termed "hackling." The hackle is composed of a number of long teeth or spikes, fixed firmly in a bench; and the workman striking the flax upon the teeth, draws it quickly through them. To persons unacquainted with this kind of work it may seem a very simple kind of operation; but, in fact, it requires as much practice to hackle well as any other operation in the whole manufacture of linen. The workmen use finer, or coarser, and wider-teethed hackles, according to the quality of the flax; generally putting the flax through two hackles, a coarser one at first, and then a finer one in finishing it. But the hand methods of breaking and scotching of flax are, however, too tedious in their operation to give satisfaction to the manufacturers in the present advanced state of mechanical science, and accordingly mills have been constructed by which these preparatory operations are much facilitated. These mills differ greatly in their form, and the mode of their operation. A very simple and efficient one is described in Gray's *Experienced Millwright*, and is constructed as follows:—Upon the main shaft, or axis of a water-wheel, is fixed a large bevilled wheel, which turns three horizontal fluted or toothed rollers, by means of a pinion on the axis of the middle one, the upper and lower rollers being kept pressed against the lower

one by weighted levers, and being carried round by contact with it. The driving-wheel likewise gives motion to an upright shaft, by means of a small pinion fixed upon the foot of the shaft; upon the upper part of this shaft are fixed cross arms, to which are attached scotches, revolving within a cylindrical casing. The rough flax is made up into small parcels, which being introduced between the middle and upper rollers, pass round the middle one, and this, either having rollers placed on its off side, or being enclosed by a curved board, turns the flax out between the middle and under rollers, when the flax is again put in between the middle and upper one, and passes round the same course until it be sufficiently broken or softened, and prepared for the scotching machine. The scotches, as before stated, are inclosed in a cylindrical casing; in the periphery of this casing are a number of apertures, and at these holes a handful of flax being held, the revolving scotches clear off the refuse.

FLEAM. An instrument containing several lancets, jointed so as to shut up into a handle in the manner of pocket clasp-knives.

FLINT. A mineral consisting of 98 silica, 0.50 lime, 0.25 alumina, 0.25 oxide of iron, 1 loss. The domestic use of this stone, for producing light by collision against steel, is well known. It is also much used in gun-locks for firing the powder. The manufacture of gun-flints employs numerous hands in this country; as independently of the large quantity required for home use, considerable shipments of them are made to various parts of the world, where the mineral is not supplied by nature. The manufacture of gun-flints was for a long time kept secret; and we are indebted to M. Dolimien for the first published account of the method practised in France, which he has given in the *Memoire de l'Institute National de Sciences.* The masses of flint which are best fitted for this purpose, are of a convex surface, approaching to globular. The best flint nodules are generally from two to twenty pounds' weight; the colour should be uniform in the same nodule; their transparency should be sufficient to admit letters to be distinguished through a piece of the stone of a quarter of a line thick, laid close upon the paper. Their fracture should be perfectly smooth and equal throughout, and the fragments slightly conoidal. The last of these properties is the most essential, since on it depends the facility with which the nodule is divided into gun-flints. All flints that prove deficient in any one of the above characters, either naturally or by a long exposure to the air, are called intractible, and rejected by the workmen. There are several hammers and a chisel employed in the operation of fashioning the flints, by which means it is said that a clever workman is able to make about a thousand flints in the space of three days. Gun-flints are also manufactured at Purfleet in Kent, and in various other parts of England, in a very superior style.

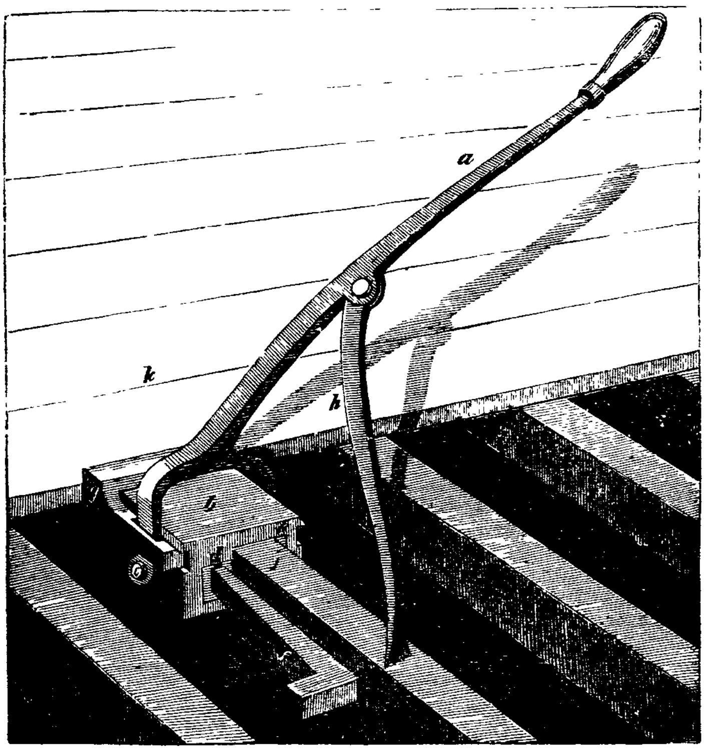
FLOAT BOARDS. Those boards which are fixed to the rim or circumference of undershot water-wheels, serving to receive the impulse of the stream, by which the mill is put in motion.

FLOATING BODIES, are those bodies which swim on the surface of a fluid, the stability, equilibrium and other circumstances of which form an interesting subject of mechanical and hydrostatical investigation, particularly as applied to the construction and management of ships and other vessels; but as the subject is one involving the higher branches of calculation, and as it is difficult to obtain practical results which shall accord with those obtained from theory, on account of the difficulty of estimating the amount of the disturbing forces, our remarks must be brief and general.

The equilibrium of floating bodies is of two kinds; viz. stable or absolute, and unstable or tottering. In the one case, if the equilibrium be deranged, the body merely oscillates about its primitive position, to which it finally returns, and this is called firm or stable equilibrium; but in the other state of equilibrium, if the system be ever so little deranged, all bodies deviate more and more, and the system finally oversets and assumes a new position; and this is called unstable or tottering equilibrium. The stability of a floating body is greater as its centre of gravity is lower than that of the displaced fluid; it is for this reason that the ballast is put in the lower part of vessels to prevent their oversetting. The nature of the equilibrium as to stability, depends on the

position of a certain point, called the meta-centre, or centre of pressure. When the meta-centre is lower than the centre of gravity, the equilibrium is tottering; when the meta-centre coincides with the centre of gravity, the body will remain at rest in any position it is placed in; when the meta-centre is above the centre of gravity, the body will always have a tendency to recover its original position, and the equilibrium will be stable.

FLOORING CRAMP. A machine invented by Mr. Andrew Smith, for laying down floors, so as to make very tight and close joints with great facility. The annexed engraving shows a perspective view of the machine as in operation, by which its construction and the mode of using it are both made apparent. *a* is a lever of the second class, about 2 feet 6 inches long, with a handle at the upper end, and forked at the lower so as to be attached to two of the opposite sides of a block of cast iron *b*, by bolts at *c*. The block *b* is about 6 inches square, and 3 deep, with a large groove capable of being increased or diminished in its depth for the reception of joists of different sizes. For this purpose, it has on one side a shifting loose cleat or plate *e*, kept in its place by stout pins; and on the other end, on the other side of the joist, there is another



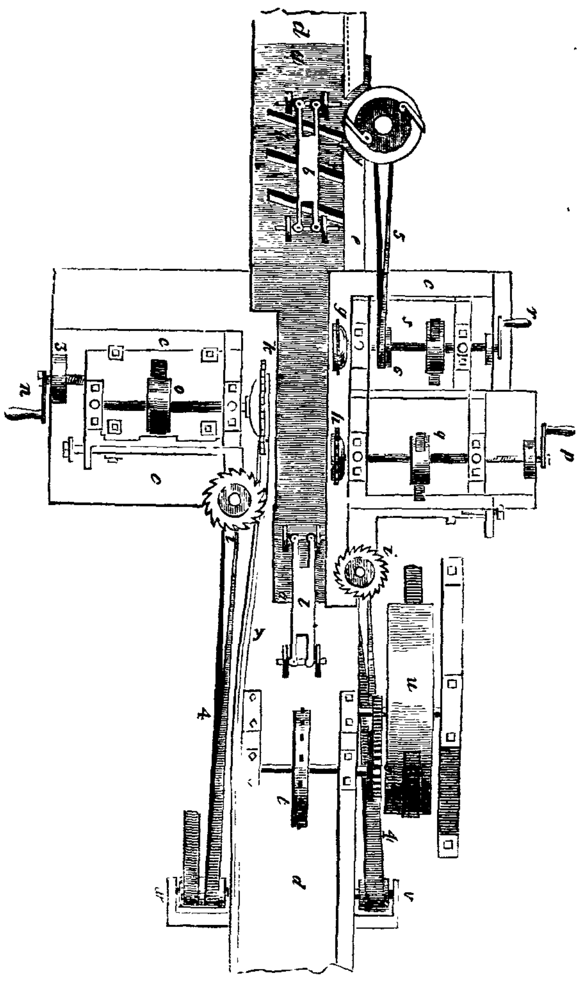
groove *d*, which contains two pieces of metal, with wedge-formed surfaces; between these the long driving wedge *f* is forced by a slight blow with a hammer, which compresses the joist between the metallic surfaces, which are jagged or armed with short projecting teeth, that fix themselves into the wood, and gripe it very fast; *g* is a movable piece of cast iron, made to press against the edge of the flooring board, with its broadest side; the two other sides or parts of this piece are stout square bars, at right angles with the other, which are inserted a part of their breadth in shallow grooves, one on each side of the

block *b*, and serve to guide the former in its action. It will be observed that the two forks of the lever *a* pass through the side bars of *g*, which therefore gives it motion. To use this machine, it is put upon the joist, and pushed up to the board laid down; a slight blow upon the wedge *f* fixes it firmly to its place; the handle of the lever is then pulled by the workman towards the boards, causing the sliding piece *g* to press the edges of the boards together with as much force as to render their junction imperceptible; the stay *h* is jointed loosely to the back of the lever *a*, and following the motion of the lever, the jagged end of its lower extremity sticks into the joist, holds the lever in the position it was drawn, and preserves the pressure against the board, while it is nailed down by the workman. To remove the cramp, all that is necessary is to strike the wedge on the opposite side, which loosens the whole, when it is drawn back to take the next board, which is operated upon in a similar manner.

FLOORING MACHINE. A machine invented by Mr. Muir, of Glasgow, the object of which is the preparation of complete flooring boards with extraordinary dispatch, and in the most perfect manner; the several operations of sawing, planing, grooving and tongueing, being all carried on at the same instant, by a series of saws, planes, and revolving chisels.

The figure in the next page represents a plan of the machine, slightly modified, to render the construction more easily understood by the reader. The machinery is adapted for the *simple planing* of boards, as well as the preparation of *square jointed* or *plain jointed flooring*. We shall commence our description by an account of those parts which constitute a simple planing machine, and then proceed to describe the apparatus by which it is adapted to the preparation of jointed flooring. The planing machine consists of a perfectly flat and straight bench, *d d d*, which should be at least twice as long as any board intended to be prepared upon it. This bench is made fast to a block of stone *c c* or other solid matter, which, together with a suitable framing, serves to keep the whole machinery as firm and steady as possible. Along one side of this bench is a raised guide *e e*, which extends as far as the circular saws *i i*, but only a part of it is shown in the figure, in order to bring some of the other arrangements more into view. About the middle of the bench a metallic plate *a a* is let in flush with its surface, which forms a durable stock for the plane irons; these plane irons are of the usual form, but of greater breadth than the boards to be planed. The projection of their cutting edge is effected and regulated by screws, and the number of plane irons employed at a time is determined by the degree of finish required for the surface of the boards; three plane irons are however generally used, as shown at *h h h*, the dark spaces being the mouths of the planes: from this it will be seen that it is the lower side of the board that is planed, and the shavings are delivered under the machine. An endless pitched chain, having catch hooks at convenient distances, takes hold of the boards as they are put into the machine in succession, and drags them along the bench; the edge of one of the sides of each board passing under a rebate in the guide or fence (as shown in the figure) prevents the board from bending upwards by the action of the chain, while it is pressed down to the plane irons by springs or weighted levers, as seen at *b b*, which are mounted upon antifriction rollers, the axles of which are so inclined as to cause the boards to be uniformly driven against the fence, and to pass in a straight line through the machine. Motion is given by a band from a large revolving drum, placed above the machine, (not shown in the figure,) which communicates with the drum *u*, upon the shaft of which is a pinion, that drives the toothed wheel *j*; the axis of the latter carries the pitched rigger *t*, round which the endless chain is passed, and stretched in a parallel direction with the bench, by passing over the pulley *z*, at the opposite end of the machine; at this place only a small piece of the chain is brought into view, as the introduction of the whole of it would hide or tend to confuse some of the other parts of the apparatus. The pulley *z* is mounted upon a tightening frame, *y*, which moves upon a joint at the lower end, the tension being increased or lessened by the wedges 1 1, or by regulating screws. The parts we have thus described constitute a separate machine for the planing only of boards. For the preparation of plain or square-jointed flooring

boards, the following additional apparatus is brought into operation. A part of the fence *e* is slightly hollowed from the direct line of the bench, to admit of projecting inequalities in the edges of the boards; these are removed by irons or cutters fixed on a horizontal revolving plate *f*, the periphery of which enters an aperture in the fence *e*; and it is on the edge of the board presented to this side of the machine that a tongue or feather is formed when required. To



produce this effect two circular saws, *g* and *h*, are used, one of which, *g*, revolves under the board, and cuts it upward; the other, *h*, revolves above the board, and cuts it downwards, to such a depth only on each side as to leave a tongue or feather of the required thickness uncut. By the progressive motion of the board it next passes under the operation of two circular saws *i*, one only of which can be seen, as the other is directly underneath on the same spindle, and separated only by a ring or washer, which is of the same thickness as the tongue. These saws, acting horizontally, or at right angles to those at *g* and *h*, cut off the superfluous wood, and leave the tongue projecting from the board completely

formed. The opposite edge of the board is cut parallel to the other by a circular saw *k* revolving vertically, which is called the "*breadthing*" saw; a guide fixed to the head of *o*, which supports the spindle of this saw (but which cannot be seen in the figure), is so placed as to conduct the superfluous pieces, separated from the boards by the saw *k*, underneath the circular saw *l*; the slips are thus removed out of the way of the latter saw and preserved. The saw *l* revolves horizontally, and is called the "grooving saw;" it is considerably thicker than ordinary circular saws, and has long teeth to admit of their receiving a "set" to cut out the whole of the required groove at one operation. The spindle head which carries the grooving saw is adjusted and fixed by screws to a bracket attached to the head *o*, the latter being placed in slides, which keep it steady, and conduct it in a parallel direction when moved to or from the bench. All the parts that operate on this edge of the board being thus connected, advance or recede together. This movement is effected by means of a screw fitted with collars to the fixed puppet 3, and working in a nut in the back part of the head *o*; the screw is turned by the handle *n*, and an index on the head *o* points out the relative position of the circular saw *k* with respect to the other side of the machine, and consequently indicates the various breadths of the finished boards by pointing to a divided scale of inches and parts fixed upon the block *c*. All the saws are fixed on to the spindles in the ordinary way, by screws, nuts, and washers; but the spindles are considerably thicker than usual, to admit of their being fitted with cutters or irons, which, by cutting horizontally, rebate the superfluous thickness of the board to a sufficient extent, from that part which is destined to form the under side of the floor in all flooring boards. The heads, which carry the vertical saws *g h*, are placed on slides fixed to the block *c c c*, their horizontal position being adjusted by regulating screws, worked by the handles *p* and *r*, and their spindles elevated or depressed by proper adjusting screws. Motion is communicated by endless bands from a large drum wheel above the machine, such bands embracing all the vertical saw pulleys, and also the rigger or pulley *w* of the intermediate shaft *v w*; and this intermediate shaft, by means of half crossed or twisted bands 4 4, gives motion to the horizontal saws *i* and *l*. The circular plate or plane *f* is also impelled by another half twisted band 5, from a pulley 6, on the axis of the saw *g*. The power which impels the whole machine is derived from a steam engine or other prime mover applied to the shaft of the large drum wheel before mentioned. Several of these machines have been for some time past in constant use; one of which, at Pimlico, we have often witnessed the successful operation of.

FLOUR. The fine particles of grain, usually obtained by grinding in a mill. See FARINA, CORN, and MILLS.

FLUID. A body whose parts yield to the slightest force when impressed, and by yielding, are easily moved against each other. Fluids are divided into *elastic* and *non-elastic*. Elastic fluids are those which may be compressed into an exceeding small compass, but which, on removing the compressing force, resume their former dimensions; and these are distinguished as airs or gases. Non-elastic fluids are those which occupy the same bulk under all pressures, or if compressible, it is only in a very slight degree, as water, oil, &c., and these are denominated liquids, except in the case of metals in fusion. The physical nature, laws, and effects, of *non*-elastic fluids *at rest*, constitute the science of Hydrostatics, and when *in motion*, of the science of Hydraulics, or Hydrodynamics; those that relate to elastic fluids appertain to Pneumatics.

FLUOR SPAR. The native fluate of lime.

FLUORIC ACID. The name given to an undecomposed substance, which, combined with lime, constitutes the fluor spar. Fluoric acid may be obtained by putting a quantity of the spar in powder into a leaden retort, pouring over it an equal quantity of sulphuric acid, and then applying a gentle heat; a gas ensues, which may be received in the usual manner in jars, standing over mercury. This gas is the fluoric acid, which may be obtained, dissolved in water, by luting to the retort a receiver containing that fluid. The distillation is to be conducted with a very moderate heat, to allow the gas to condense, and to

prevent the fluor itself from subliming. The properties of this acid are, that, as a gas, it is invisible and elastic like air; but it will not maintain combustion, nor can animals breathe it without death. In smell it is pungent, something similar to muriatic acid. It is heavier than common air, and corrodes the skin. When water is admitted in contact with this gas, it absorbs it rapidly; and if the gas be obtained by means of glass vessels, it deposits, at the same time, a quantity of silica. Water absorbs a large portion of this gas; and in that state it is usually called fluoric acid by chemists. It is then heavier than water, has an acid taste, reddens vegetable blues, and has the property of not congealing till cooled down to 23°. The pure acid may be obtained again from the compound by means of heat. Fluoric acid gas does not act upon any of the metals; but liquid fluoric acid is capable of oxyding iron, zinc, copper, and arsenic. It does not act upon the precious metals, nor upon platina, mercury, lead, tin, antimony, cobalt. It combines with alkalies, earths, and metallic oxides, and, with them, forms salts denominated fluates, of which the true fluor, Derbyshire spar, or fluate of lime, consists of—

Lime	57
Fluoric acid	16
Water	27
	100

The most remarkable property is that already alluded to, viz. the facility with which it corrodes glass and siliceous bodies, especially when hot, and the care with which it holds silica in solution, even when in a state of gas. This affinity for silica is so great that the thickest glass vessels can withstand its action only a short time. With respect to the nature of the substance usually termed fluoric acid, it has not yet been determined experimentally whether it be really a compound of some unknown base with either oxygen or hydrogen, or whether it be a simple substance like chlorine. Dr. Thompson inclines to the opinion that it is a compound of an unknown radical with hydrogen, and not with oxygen; but Sir H. Davy made several attempts to separate its hydrogen, but without success, although he applied the power of the great voltaic batteries of the Royal Institution to the liquid fluoric acid; neither could he decompose it by passing it with chlorine through a platina tube heated red hot, nor by distilling it from salts containing abundance of chlorine or of oxygen. Dr. Ure therefore observes, that by the strict rules of chemical logic, fluoric acid ought to be regarded as a simple body, for we have no evidence of its having ever been decomposed; and nothing but its analogy with the other acid bodies has given rise to the assumption of its being a compound.

FLUORINE. The imaginary radical of the above acid.

FLUTE. One of the simplest musical instruments of the wind kind. It is played with a mouth-piece at the end, and the notes are changed by opening or stopping the holes ranged along the side. The German flute differs from the former, the end not being put into the mouth, but closed by a plug, and the lower lip being applied to a hole about three inches from that end. As usually constructed, this instrument has six open holes, and a seventh hole closed by a key, as in hautboys, bassoons, &c.; but numerous improvements have been made in them, and they are now frequently made with eight or even ten keys, by which the fingering of many musical passages is much facilitated.

FLUX. A general term used to denote any substance or mixture added to assist the fusion of minerals. In the large way, limestone and fusible spar are used as fluxes. The fluxes made use of in philosophical experiments consist usually of alkalies, which render earthy mixtures fusible by converting them into glass, or else glass itself into powder. Alkaline fluxes are either the crude flux, the white flux, or the black flux. Crude flux is a mixture of nitre and tartar, which is put into the crucible along with the metal intended to be fused. White flux is formed by projecting equal parts of a mixture of nitre and tartar, by moderate proportions at a time, into a red hot crucible. In the detonation which ensues, the nitric acid is decomposed and flies off with the tartaric acid,

and the remainder consists of the potash in a state of considerable purity. Black flux consists of two parts of tartar to one of nitre, on which account the combustion is incomplete, and a considerable portion of the tartaric acid is decomposed by mere heat, and leaves behind a quantity of charcoal, on which the colour depends. It is used in the reduction of metallic ores, which it effects by combining with the oxygen of the oxide. Mowean's reducing flux is made of eight parts of pulverized glass, one of calcined borax, and half a part of charcoal. Care must be taken to use a glass which contains no lead.

FLY, in Mechanics, a wheel with a heavy rim, placed on the shaft of any machinery put in motion by any irregular or intermitting force, for the purpose of rendering the motion equable and regular by means of its momentum. This effect results from a law of nature, that all bodies have a tendency to continue in their state either of motion or of rest, until acted upon by some extraneous force. Thus the rim of a fly-wheel, after a few revolutions, acquires a momentum sufficient to cause it to revolve with a velocity depending upon the resistance of the machinery; and the augmentations and diminutions of the impelling power succeeding each other rapidly, neither cause acts sufficiently long to either augment or diminish the velocity acquired in any considerable degree, so that it remains equable, or nearly so. Thus in the case of a man working at a winch, the power which he exerts in pulling upwards from the lower part considerably exceeds his power in thrusting forwards in the upper quarter; but before the extra force thus exerted has acted sufficiently long to change the velocity of the wheel, the winch arrives at the point where his force is the least, by which time the excessive force previously exerted having taken effect, the equable motion of the fly is maintained; and the resistance of the work being equalized, a man is enabled to raise throughout a whole day a weight of forty pounds with more ease than he could raise thirty pounds without a fly. In all cases where a rotatory motion is to be obtained from a reciprocating one, by means of a crank, a fly-wheel is necessary to continue the motion at those two points of the revolution in which the crank lies in the direction in which the moving force acts; for in this case the crank affords no leverage to the power either on one or other side of the fulcrum, and consequently no motion could be produced in either direction; but the momentum acquired by the fly urges the crank forward in the direction in which it was previously moving, and continues the rotation until the crank is brought into such a position as to offer sufficient leverage to the power to maintain the impetus of the fly.

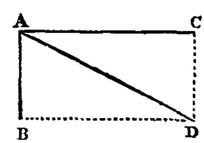
FOCUS, in Optics, a point wherein several rays concur or are collected, after having undergone either reflection or refraction. The point is thus denominated because the rays being here brought together and united, their joint effect is sufficient to burn bodies exposed to their action; and hence this point is called the focus, or burning point.

FOIL, among jewellers, a thin leaf of metal placed under a precious stone, in order to increase its brilliancy, or give it an agreeable and different colour. These foils are made of either copper, gold, or gold and silver together; the copper foils are commonly known by the name of Nuremberg, or German foils. They are prepared as follows:—Procure the thinnest copper plates you can get; beat these plates gently upon a well polished anvil with a polished hammer, as thin as possible; and placing them between two iron plates as thin as writing paper, heat them in the fire; then boil the foils in a pipkin, with equal quantities of tartar and salt, constantly stirring them, till by boiling they become white; after which, taking them out and drying them, give them another hammering, till they are made fit for your purpose; however, care must be taken not to give the foils too much heat, for fear of melting, nor must they be too long boiled, for fear of attracting too much salt. The manner of polishing is as follows:—Take a plate of the best copper, one foot long and about five or six inches wide, polished to the greatest perfection; bend this to a long convex, fasten it upon a half roll, and fix it to a bench or table; then take some chalk, washed as clean as possible and filtered through a fine linen cloth, till it is as fine as you can make it; and having laid some on the roll, and wetted the copper all over, lay your foils upon it, and with a polishing stone and the chalk,

polish your foils till they are as bright as a looking glass: after which they must be dried, and laid up secure from the dust.

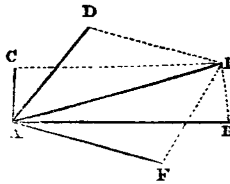
FOOT. A measure of length, consisting of twelve inches, each inch being three barley corns, or twelve lines. The square foot is a measure for surfaces, being a square of which each side is 12 inches; consequently a square foot contains 144 inches. The cubic foot is a measure for capacity, or solid contents; it is a foot in length, in breadth, and in depth or thickness, and contains 1728 cubic inches.

FORCE is the name applied in Mechanics to whatever produces motion or pressure. Thus we have the forces of gravity and of elasticity, muscular force, and that of electricity and magnetism. These will be considered under the head PRIME MOVERS; at present we shall confine ourselves to the general laws to which the application of force is subject. When a force is applied suddenly to a body, and immediately ceases to act upon it, it is called an impulsive force; but when its action is continued so as to produce a constantly increasing motion or pressure, it is termed a constant or accelerating force. Examples of the first kind are seen in the blow with a hammer, and in the discharge of a gun; and of the second, in the action of gravity and in the motion of the wind. Impulsive forces produce uniform velocities. Thus, if a billiard ball be struck, and move along a smooth table, so that the resistance arising from friction may be small, it will be observed to pass over equal spaces in equal successive portions of time; or, in other words, if the ball pass over 1 foot in a second, it will pass over 2 feet in two seconds, 3 feet in three seconds, and so on. Constant forces produce accelerated velocities. Thus, if a certain force, as that of gravity, act upon a body so as to impel it through 16 feet in one second of time, in the next second it would pass through three times sixteen, or 48 feet; in the third second through five times sixteen, or 80 feet, and so on, the constant addition being 32 feet, which is the velocity acquired at the end of the first second of time. Now if a force produce an uniform increase of velocity, as in this case, it is called an uniformly accelerating force; or if it produce a regular diminution of velocity, it is a uniformly retarding force. If, however, the increase or decrease of velocity be not constantly the same, it is caused by a *variable* accelerating or retarding force. In the application of forces, the chief considerations are intensity and direction. If a single force act upon a body, motion necessarily results in the direction in which the force acts, and with a velocity proportional to its intensity. If two or more forces are employed, motion may or may not result, according to the intensity and direction of the force. If two equal forces applied to the same point act in opposite directions, they mutually annihilate each other; if, however, they act in the same direction, they produce the same effect as a single one equal in intensity to the sum of the two. Or, if they act in different directions, forming an angle with each other, a third force may be assigned, which shall be equivalent to the other two. In this case the two forces are called the components, and the third, the resultant. The process for finding the resultant of two or more forces is called the *composition of forces*, and the finding of two or more forces, which shall be equivalent to a single given force, is termed the resolution of forces. The propositions connected with this subject form a highly interesting and important branch of the science of mechanics. In the annexed cut let the line A B represent the intensity and direction of one force, and A C the intensity and direction of the other force. Complete the parallelogram A B D C, and the diagonal A D will represent the intensity and direction of the resultant; *i. e.* a force equal to A D, and, in the direction D A, would counterbalance the other two, and keep the point A at rest. The same may perhaps be more clearly apprehended by considering the point

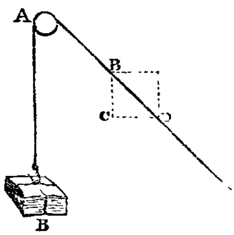


A in motion; let a force act upon A so as, if alone, to drive it to the point B in one second, and at the same instant let a force act in the direction A C, that would, if unopposed, carry it to C in the same time; then if the two forces act together, the resulting motion will be in the line A D, and the body will reach

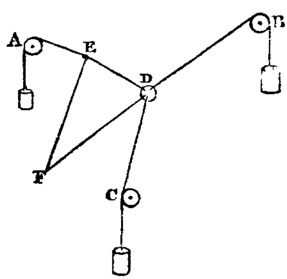
the point D in the same time that it would have taken to reach B or C by the action of either of the forces singly. In the composition of forces it will be seen that we are limited to one resultant; but in the resolution of force we may have an infinite number of components, any pair of which will be equivalent to the given force. Thus let a force, represented by the line A B, be resolved into two others by drawing two parallelograms around it, it will be manifest that the component forces may be either A C and A E, or A D and A F; and as an infinite number of directions may be given to the lines A C, A E, the number of components is also unlimited. In general, however, the required direction and intensity of one of the forces is given, and this determines the other.



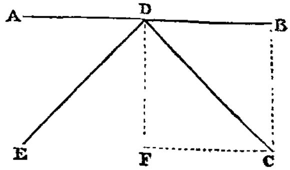
Suppose a man were required to raise a weight over a pulley, and the ropes, instead of being parallel, are in the directions A B A D, it will be evident that a part of his strength is employed uselessly in pulling horizontally. Let B D represent the force necessary to sustain the weight B; resolve this into the two B C, B D, the one perpendicular, and the other parallel to the horizon, it will then be seen that the force which is employed in raising the body, is equal to B C, and as this is less than B D, the weight must fall, or the power be increased in the ratio of B C to B D.



If three forces are employed, they may also be determined by drawing three lines parallel to their directions, so as to form a triangle. The three cords A D, B D, C D, will be kept at rest, when the three weights at A B C are proportional to the three lines D E, D F, and E F, either of which may be considered as the resultant of the other two. If a number of forces act upon a body, and a single resultant be required, it may be found by finding the resultant of one pair, and connecting this with another; then find the resultant of this pair and connect it with the next, and so on, till the last is obtained, which is the common resultant of the whole.



Numerous examples are daily presented of the composition of forces. When a boat is rowed across a river in which there is a rapid current, it will not pass directly across, nor down the stream, but will partake of both directions, proceeding in a direction intermediately between the acting forces. A body falling from the topmast of a vessel in full sail will not fall directly downward, for having a direction forward given by the motion of the vessel, and a downward direction by gravity, it will take a middle course, describing what is termed a parabolic curve. The tide and wind acting together upon a vessel, the two oars of a boat in rowing, the motion of a stone, an arrow, or a cannon ball through the air, are examples of the same kind. Another instance of a resultant motion may be adduced, in the reflection of elastic bodies from a smooth surface. Let A B be a smooth flat surface, and let an elastic ball strike it in the direction C D, then will it be reflected in the direction D E, making the angle of reflection E D F equal to the angle of incidence C D F. If C D represent the force of the ball in the direction C D, it may be resolved into two, which are proportional to C F and C B. The

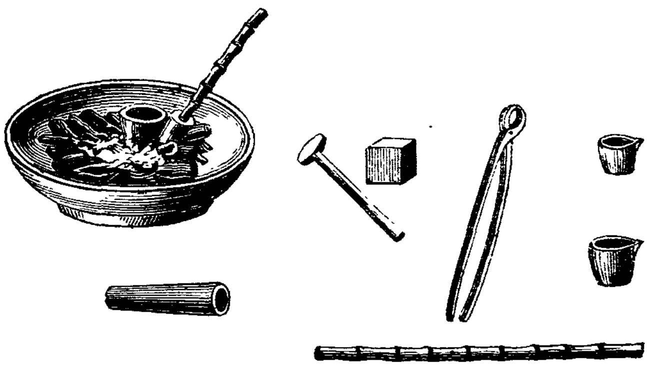


force C F being parallel to the plane A B, is not influenced by it, but C D being

perpendicular, is destroyed, and a motion impressed in the direction D F. The body is still then under the influence of two forces, its retained velocity in the direction D A, and, the impressed force produced by the reaction of the board in the direction D F. Between these two the ball necessarily moves in the line D E. An application of this problem will account for the motion of billiard balls, and of ships sailing obliquely to the wind; also of windmill sails, and other daily occurrences in nature and art.

FORCEPS. A general term, (but principally used in surgery,) for a variety of instruments of the nature of tongs or plyers.

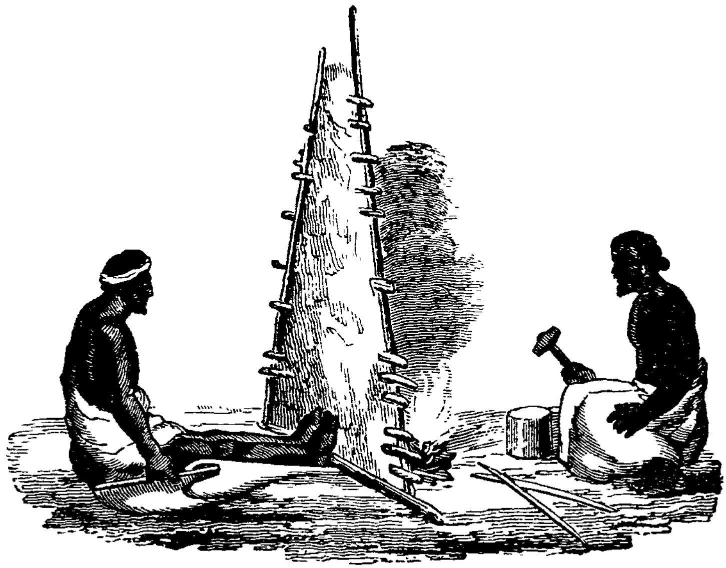
FORGE properly signifies a little furnace, furnished with a pair of bellows to render the combustion more vivid; and employed by smiths and other artisans in iron, steel, &c. to heat their metals, in order to soften and render them more manageable upon the anvil. In laboratories there is generally a small furnace, consisting of a cylindrical piece, open at top, which has at its lower end a hole for receiving the nozle of a pair of double bellows. This kind of forge is very convenient for fusions, as the operation is quickly performed, and with few coals. The natives of Ceylon work with considerable skill and taste in gold and silver; and, with means that appear very inadequate, execute articles of jewellery that would certainly be admired, but not very easily imitated in this country. The best artists require only the following apparatus and tools, a low earthen pot, full of chaff or saw dust, in which he makes a little charcoal fire; a small bamboo blow-pipe, with which he excites the fire; a short earthen tube or nozle, the extremity of which is placed at the bottom of the fire, and through which the artist directs the blast of the blow-pipe; two or three small crucibles made of the fine clay of ant-hills, a pair of tongs, an anvil, two or three small hammers, and a file; and to conclude the list, a few small bars of iron or brass, about two inches long, and differently pointed for different kinds of work.



It is astonishing what an intense little fire, more than sufficiently strong to melt gold and silver, can be kindled in a few minutes. Such a simple forge deserves to be better known; it is, perhaps, even deserving the attention of the scientific experimenter, and may be useful to him when he wishes to excite a small fire larger than can be produced by the common blow-pipe, and he has not a forge at command. The success of this little forge depends a good deal in the bed of the fire being composed of a combustible material, and a very bad conductor of heat. The blacksmiths of Ceylon are not behind their brethren, the jewellers, in the simplicity of their apparatus, however inferior they may be in skill.

The cut in the next page represents two smiths at a forge. The bellows consist of a couple of bags made of bullocks' hides, each furnished with a bamboo nozle, and a long slit as a mouth, with wooden lips, that are opened and drawn up and shut and pressed down alternately by the hands of the person sitting between the pair, who keeps up a constant blast by the alternate action of the two. The nozle of the bellows is introduced through a small hole in the foot of the screen, which constitutes the back of the forge, and serves to allow the ascent

of the smoke. It is composed of a mat or hurdle, supported between two sticks, and plastered over with clay to protect it from the heat. Mr. J. Sperne,



of Belper, near Derby, has invented a forge, principally designed for the manufacture of nails, which is highly deserving of notice. It is peculiarly adapted for the burning of charcoal; and the inventor proposes to adopt this fuel in conjunction with coke, or coal purified from sulphur, generally in the proportion of three parts of the latter to one of the former; these proportions to be, however, varied according to the nature of the coal, and the quality of the metal to be wrought. This forge is constructed as follows:—the brickwork is first carried up from the bottom of a cylindrical figure, to the height of twenty-four inches, leaving proper apertures for the delivery of the ashes, the reception of the water troughs, and for the insertion of the nozle of the bellows; the circular aperture in the centre is then covered with a fine cast-iron grating, which forms the bottom of the furnace. The courses of brick-work are next carried up a foot higher, and the whole is then surmounted by a cast-iron plate, with a rim or border six inches high round the external periphery, forming a convenient dish for holding the fuel to replenish the fire. In the centre of the cast-iron top plate is an aperture corresponding with the fire-place, and to this aperture is fitted a cast-iron ring, supporting, on three cast-iron pillars, another ring which carries the brick-work of the chimney, which is cylindrical. The bellows are suspended from a frame, and are worked by a lever which encircles the chimney, affording every workman employed the convenience of acting upon it with facility; and as this construction of the forge will admit of six workpeople being employed round it in making of nails, the fire is always kept up bright and vivid by the continual blasts from the bellows. With respect to the advantages of the forge the inventor observes—"By the peculiar construction of the fire-place, wood charcoal alone may be used, which cannot be done in other forges; but by a mixture of wood charcoal with coke for fuel, the metals to be wrought will acquire a surprising degree of malleability, and weld with great ease; their tenacity and clearness will also be improved, and they will have, when cold, a better face or skin than can be put upon them by any other method. In addition to the great advantage of apportioning the

fuel to the work required, the circular form will admit of a greater number of workmen being employed at the same time at this forge than at any other, thereby causing a saving of brickwork in the erection of forges, of bellows, and shoproom for working them, and a permanent saving in the fuel for their consumption. See IRON.

FORK. A well-known instrument, consisting of a handle, and two or more prongs. Though considered now to be indispensable, it did not come into use till the reign of James I.

FORM. In Printing, an assemblage of letters, words, and lines, arranged in order, and disposed into pages by the compositor; from which, by means of ink and the press, sheets are printed. Every form is enclosed in an iron chase, wherein it is firmly locked by a number of wedge-shaped pieces of wood of various sizes. There are two forms required in every sheet, one for each side: and each form consists of more or fewer pages, according to the size of the book. See PRINTING.

FORMIATES. Compounds of the formic acid with earths, alkalies, and metallic oxides.

FORMULA. A general rule or expression for resolving certain particular cases of some problem.

FOTHERING. A method sometimes resorted to for stopping a leak in a vessel at sea. It consists in stitching loosely a quantity of oakum upon a sail, which is drawn under the vessel's bottom; and by the flow of the water through the leak, the oakum is drawn into the aperture.

FOUNDING is the art of casting or forming of melted metal an infinite variety of articles to any given pattern or design; and the place or building where the art is carried on is called a foundry. Foundries are, however, distinguished either by the metals they work or the articles they fabricate, such as brass foundries and iron foundries, bell and type foundries. As the methods of casting in one kind of metallic substance are very similar to those employed in others, we shall therefore describe at some length the art of founding as it is practised by the brass founders, and more briefly whatever is peculiar in the processes adopted in the other branches of the art.

The operations of the brass founder are not limited to that peculiar yellow compound of copper and zinc, strictly termed brass, but to every variety of the alloys of copper, with tin and zinc in every proportion, according to the purposes for which the article is required, or according to the motive of economy or profit of the manufacturer. Founders in brass require an exact model in wood, or otherwise, of the article to be founded; and this is most frequently made in two parts, exactly joined together, and fitted by small pins, and the casting, in such a case, is performed by two operations, that is, one half at one time, and one half at another, and in the manner following; viz. the founder provides himself with a yellowish sharp sand, which is required to be well washed, to free it from all earthy and other particles. This sand is prepared for use by a process called tewing, which consists in working up the sand in a moist state, over a board about one foot square, which is placed over a box to receive what may fall over in the tewing. A roller about two feet long and two inches in diameter is employed in rolling the sand about until it is brought into that state which is deemed proper for its business; a long-bladed knife is also required to cut it in pieces. With the roller and the knife, the tewing is finished for use by being alternately rolled and cut. When the sand is so far prepared, the moulder provides himself with a table or board, which, in size, must be regulated by the castings about to be performed on it. The edges of the table or board are surrounded by a ledge, in order to support the tewed stuff; the table, so previously prepared, is filled up with the sand as high as the top of the ledge, which is in a moderately moistened state, and which must be pressed closely down upon the table in every part. When the operation has so far advanced, the models must be all examined, to see that they are in a state to come nicely out of the mould, and if not found so, they must be cleaned or altered till the founder is satisfied with them. All models require the greatest accuracy in their making, or it will be vain to suppose any thing good can be

performed by the founder. When the models are in a proper state to be founded, one half, generally longitudinally, is taken first, and this is applied on the mould, and pressed down into the tewed stuff or sand, so as completely to leave its form indented on it, which must be very carefully looked to, and examined minutely, to see that there are no small holes, as every part in the indented sand must be a perfect cameo of the models submitted and pressed into it. If it should not be found perfect, new sand must be added, and the model re-indented and pressed into it, till it leaves its impression in a state proper to receive the metal. In the same manner, other models intended to be founded on the same table must be prepared and indented into the sand. When the table is completely ready for the metal it is carried away to the melter, who himself examines its state, and also the cameos, and who lays along the middle of the mould the half of a small wire of brass, which he presses into the sand, so as to form a small channel for the melted brass to flow in, and which he terms the master jet or canal. It is so disposed as to meet the ledge on one side, and far enough to reach the last pattern on the other; from this is made several lesser jets or branches, extending themselves to each pattern on the table, by which means the fluid metal is conveyed to all the different indented impressions required to be cast on the table. When the work is so far forwarded it is deemed ready for the foundry; but previously to this, the whole is sprinkled over with mill dust, and when it is so sprinkled the table is placed in an oven of moderate temperature till it gets dry, or in a state which is deemed proper to receive the melted brass. The first table being thus far completed, it is either turned upside down, and the moulds or patterns taken out, or the moulder begins to prepare another table exactly similar to the one he has just completed, in which he indents and presses the other half of the mould; or he turns the table already finished, containing the first half of the patterns, upside down; previously, however, to doing this, it will be necessary for him to loosen the pattern, which is fixed in the sand, a little all round, with any small instrument that will open away the sand from its edges, in order to its coming out of the table more easily. This economy in founding, of making one half of each pattern to be cast answer the purpose of the whole pattern, is a very common practice in brass founding, and enables the manufacturer to sell his goods at a much cheaper rate than he would otherwise be enabled to do if he was obliged to have a full pattern of all goods to be founded. When he has loosened the sand from about the pattern, and taken it out of the first table, the work is proceeded in of preparing the counterpart or other half of the mould with the same pattern, or otherwise, and in a frame exactly corresponding with the former, excepting only that it is prepared with small pins to enter holes which are made in the first half of the model, to secure them together. When this counterpart table has been finished, and all the patterns indented in the sand, it is carried to the melter, who, after enlarging the principal jet of the counterpart, and making the cross jets to the various patterns, and sprinkling them as before with mill dust, it is set in the oven to be sufficiently dried to receive the liquid metal. When both parts are sufficiently dry, they are joined together by the pins, and to prevent these from being forced open by the pressure of the liquid metal, the tables are further secured by screwed bolts or wedges. The furnace for melting is somewhat similar to a smith's forge, with a chimney over it, and a pair of large bellows; the hearth is of masonry or brickwork, secured by an outer rim of iron. The fire-place, which is in the centre, is a cavity of 12 to 18 inches square, and reaching down to the floor of the foundry. The lowest part of this cavity constitutes the ash-pit and air-chamber, and is divided from the upper portion by an iron grating; on this the fuel is deposited, in the centre of which is placed a covered crucible, containing the metal under fusion, which is accelerated by keeping the fuel in which it is completely imbedded in vivid combustion by the continued action of the bellows. When the fusion is perfect the crucible is withdrawn from the fire by the caster, with a pair of long tongs adapted to gripe it firmly, and with which he pours into the master jet of each mould until they are filled. As soon as this is done water is sprinkled over the tables to cool and fix the metal; after which the tables are unfastened,

and the new castings taken out, to be finished by filing, scouring, burnishing, turning, &c. as the work may require. The sand is now taken out of the frames, to be worked up again for the next casting: by repeated use the sand becomes black, by the charcoal collected from the foundry, which does not, however, unfit it for further employment. To reduce the expense and weight of casting large masses in solid metal, recourse is often had to forming them hollow, which process is distinguished by the term *core casting*, as it is necessary to have a core or heart of nearly the shape of the external form of the pattern. This core is usually made of clay, mixed and kneaded with crucible dust, and is suspended by wires in its place, with a space around it to receive the metal; in small articles, however, it is usual to fill up the space by coating the core to that extent with wax, which melts as the metal flows to supply its place. When the pattern is of a complicated form, and a difficulty arises in getting out the core, it is usually separated into several pieces, which are joined together after being cast. In many of the Birmingham manufactures the cores occupy so much of the pattern, that the metal left is not thicker than a shilling. The business of a brass founder, contrary to that of an iron-founder, extends to the finishing of the articles he casts; and not only to this, but to the manufacture of brass goods that are not cast or founded at all, being made entirely from wrought or rolled metal. A large proportion of the Birmingham manufacture of cabinet brass work is formed out of sheet metal, by pressure between dies after the manner of coining: such goods are in consequence cheaply made, and frequently are impressed with very tasteful and elaborate designs. The castings, when taken out of the sand, have first to be cleaned up and completed, as they are seldom free from defects; the cores are filed off, and the small cavities filled up with metal or solder; they are afterwards finished, according to the nature of the article, by filing, turning, burnishing, and lackering. The superior kinds of brass work are gilded, which preserves them better than lacker, and constitutes the article called *or molu*.

In the founding of statues, busts, &c. three things in particular require attention; namely, the mould, the wax, and shell or coat, the inner mould or core, so called from being in the middle or heart of the statue. In preparing the core, the moulder is required to give it the attitude and contour of the figure intended to be founded. The use of the core is to support the wax and shell, to lessen the weight, and save the metal. The core is made and raised on an iron grate, sufficiently strong to sustain it; and it is farther strengthened by bars or ribs of iron. The core is made of strong potter's clay, tempered with water, and mixed up with horse-dung and hair, all kneaded and incorporated together; with this it is modelled and fashioned previously to the sculptor's laying over it the wax; some moulders use plaster of Paris and sifted brick-dust, mixed together with water, for their cores. The iron bars which support the core are so adjusted that they can be taken from out of the figure after it is founded, and the holes are restored by solder, &c.; but it is necessary in full sized figures to leave some of the iron bars affixed to the figure to steady its projecting parts. After the core is finished, and got tolerably firm and dry, the operation of laying on the waxen covering to represent the figure is performed, which must be all done, wrought, and fashioned, by the sculptor himself, and by him adjusted to the core. Some sculptors work the wax separately, and afterwards dispose and arrange it on the ribs of iron, filling up the void spaces in the middle afterwards with liquid plaster and brick-dust, by which plan the core is made as, or in proportion to, the sculptor's progress in working the wax model. Care must be taken, however, in modelling the wax in both cases, to make it of an uniform substance, in order to the metal being so in the work, of which the wax is its previous representative. When the waxen model is finished to the core, or adapted and filled afterwards, small tubes of wax are fixed perpendicularly to it from top to bottom, to serve not only as jets to convey the melted metal to all parts of the work, but as vent holes to allow a passage to the air generated by the heated brass in flowing into the mould, and which, if not admitted readily to escape, would occasion so much disorder in it as would much injure

the beauty of the work. Sculptors adjust the weight of the metal required in this kind of founding by the wax taken up in the model. One pound of wax so employed will require ten pounds of metal to occupy its space in the casting. The work having advanced in progress so far, will now require covering with a shell. This consists of a kind of coat laid over the wax, which, being of a soft nature, easily takes and preserves the impression, which it afterwards communicates to the metal upon its occupying the place of the wax, which is between the shell and core. The shell is composed of clay and white crucible dust, well ground, screened, and mixed up with water to the consistence of paint, like which it is used. The moulder applies it, by laying it over the wax with a camel's hair or other soft pencil, which will require eight or nine times going over, allowing it time to dry between each successive coat. After this coating is firm upon the wax, and which is used only to protect it from those which are to follow, the second part or coating is made up of common earth, mixed with horse dung; this is spread all over the model, and in such thickness as to withstand, in some measure, the weight of the metal. To this coating or impression is added a third, composed almost wholly of dung, with a proportion of earth sufficient only to render it a little more tough and firm when used. When this is tolerably dry, the shell is finished by laying on several more coats or impressions of the same composition, made strong and stiff by successive workings with the hand. When this is finished and is deemed adequate to support the heated metal, it is further secured and strengthened by several bands or hoops of iron, bound round it at about six inches from each other, and fastened at bottom to the grate on which the statue stands. Above the head of the statue is made an iron circle, for the purpose also of confining the shell and statue; to this circle the hoops are fastened at top. It may be considered, when the moulding has arrived at this state, to be in a condition to receive the melted metal; but it is not so exactly, as will soon appear. The mould, as has been before observed, is made upon an iron grate; under this grate is a furnace and flue, in which, at this period of the work, a moderate fire is to be made, and the aperture of communication therewith stopped up, so as to keep in the heat. As the heat increases and begins to operate upon the mould, preparation must be made to allow of the wax running freely from out of the shell; for this purpose pipes are contrived at the base of the mould so that it may run gently off and through these pipes. As soon as it is all run off the pipes are nicely stopped up with earth to prevent the air entering them, &c. When this is done the shell is surrounded by any matter that has non-conducting properties—for instance, pieces of brick put round and piled up of good thickness, secured by earth, will answer the end; and the whole should be finally coated outside with loam as a further protection to keep in the heat. After the shell is adequately surrounded with materials to keep off the effect of the air, the fire in the furnace is augmented till such time as both the matter surrounding the shell and it also becomes red hot, and which, in ordinary circumstances, will take place in twenty-four hours' time; the fire is then extinguished, and the whole allowed to cool; after which, the matter which has been packed round the shell is taken away, and its place occupied with earth moistened and closely pressed to the mould in order to make it more firm and steady. It will, when having advanced so far, be in a state to receive the melted metal, to prepare which for the casting, a furnace is made a few feet above the one employed to heat the mould; it is formed like an oven, having three apertures, one of which is for a vent, the other to admit the fuel, and the last to let the melted metal flow through and out of the furnace. This last aperture should be kept very close whilst the metal is fusing, when it has arrived at that state which is deemed proper for running it into the shell, and which is known by the quick separation and escape of the zinc of the brass. A little tube is laid to convey it into an earthenware basin, which is fixed up over the top of the mould; into this basin all the large branches from the jets enter, and from which is conveyed the metal into all parts of the mould. The jets are all stopped up with a kind of plugs, which are kept close till the basin which is to supply the metal be full. When the furnace is first

opened for this purpose the melted brass gushes forward like a torrent of fire, and is prevented from entering any of the jets by the plugs, till the basin is sufficiently full to be ready to begin with the mould, and which is esteemed so when the brass it contains is adequate to the supply of all the jets at once, upon which occasion the plugs from all of them are withdrawn. The plugs consist of a long iron rod, with a head at one end, capable of filling the whole diameter of each tube. The hole in the furnace in which the melted metal is contained is opened with a long piece of iron fitted on the end of a pole, to allow of the furnace man keeping at a distance from it, as many accidents occur by the red hot metal coming in contact with the air, particularly if it be damp, in which case the most violent explosions take place. The basin is filled almost in an instant after the furnace plug is withdrawn, and the metal is then let into the several jets communicating with the model, which, when they have emptied themselves into the shell or mould, the founding is finished in so far as the casting is concerned. The rest of the work is completed by the sculptor, who takes the new brass figure from out of the mould and earth in which it was encompassed, saws off the jets, and repairs and restores the parts where required. His tools for this purpose consist of chisels of various sizes, gravers, punches, files, &c.

In casting colossal statues a somewhat different mode is pursued than the one already described, and this arises wholly from the size, it being found difficult to remove the moulds of such colossal works; to obviate this difficulty, it is worked and prepared upon the spot where it is to be cast. There are two ways of performing this, and some founders prefer the one and some the other. By the first plan, a square hole is dug into the earth somewhat larger than would be required for the mould, and its sides are hemmed up with brickwork; at its bottom is formed a hole, below the one already prepared, as a furnace, which must be built up with brickwork, having an aperture made outwards into another pit prepared near it, from which the fuel is put into the furnace. The top of the furnace in the first hole is covered by a grating of iron, and on this is moulded and placed the case of the statue to be cast, and also its waxen coating; in doing which the same process is observed by the sculptor as that already described. Near the edge of the large pit in which the model is placed is erected the furnace to melt the metal, and which is similar to the one already described for common figure casting, except being of larger dimensions; it has, like that, three apertures—one for putting in the wood, another for a vent, and a third to run the metal out at. By the second plan of founding colossal figures, it is thought sufficient to work the model above ground, adopting the same mode with respect to a furnace and grate underneath it; for whether under ground or above it, to keep in the heat when drying the core and melting the wax, is the end more particularly sought; to do which in the most effectual way four walls of brickwork are built up round the model, in the middle of which is fixed the grate and furnace; and on one side above is formed the mass of building intended for the furnace, which is to be appropriated to the melting of the metal. When the whole is finished and ready, a fire is made in the fire-place under the core of the model, and kept up so as to produce a moderate heat to dry the core, and also to melt the wax from off it, which runs down by tubes, as has been before remarked, and indeed no difference whatever takes place in such founding, except every thing being upon a larger scale. When the wax is run off and the fire extinguished in the furnace, bricks are filled in at random, either into the hole, if founding under ground, or into the area between the walls, if above ground; after this is done, the fire in the furnace is again lighted, and blown up and augmented till such time as both the core and bricks are of a red heat, when the fire is again extinguished, and the whole is left to cool; and when cooled, the bricks are removed, and all is cleared away, and the space again occupied by moistened earth to secure and steady the model. Nothing now remains but running in the metal, which is performed, as has been before described for smaller foundings of statues.

The casting of guns is performed in the manner already described for statues,

excepting that no core is required, it being cast solid, and the cavity entirely bored out, during which operation the gun is turned and finished on the outside. (See CANNON, and BORING MACHINE.) The composition of which cannon is formed in this country is 10 lbs. of tin to 100 lbs. of copper, whereas, in the brass of statues, zinc is employed instead of tin.

Founding in Bronze.—The Egyptian bronze consisted, according to Bessari, of two-thirds brass and one-third copper. Pliny says, that the Grecian bronze was formed by adding one-tenth lead and one-twentieth silver to the two-thirds of brass, and the one-third of copper of the Egyptian bronze; and that this was the proportion afterwards made use of by the Roman statuaries. The modern bronze is commonly made of two-thirds copper, fused with one-third of brass, and recently, owing to the great demand for ornaments and decorative furniture of this alloy, lead and zinc in small proportions have been added to the copper and brass. These additions, it is said, increase the fusibility of the alloy, and facilitate the process of casting. Bronze casting is employed in forming equestrian statues, colossal and other figures in alto relievo, to adorn public places, its peculiar tint finely contrasting with the stone or marble of architecture, especially when the artist displays taste in his design and skill in his execution. The casting in bronze is performed in the following manner: first, the figure or pattern to be cast must have a mould, and this is prepared and laid on a plaster cast, previously wrought and finished by the sculptor. The mould is made of plaster of Paris, moistened with water, to which is added brick-dust in the proportion of one-third of the former to two-thirds of the latter. This is carefully laid on the mould, with strength in proportion to the weight of metal intended to be used in the founding. In its joints should be cut small channels tending upwards and from different parts of the internal hollow, to allow of vent for the air to escape, as the heated metal runs in upon the mould. A thin layer of clay should be spread over the inside of it, and of the thickness which it is intended the bronze should be. Withinside of the clay a filling-up of plaster and brick-dust, in the proportions as before described, will be required to compose the core; but if the work to be cast be large, before the plaster and brick-dust are poured into the mould to form the core, a skeleton, composed of iron bars, as a support for the figure, should be prepared and fixed; after which the filling up of the core may be proceeded in. When this is done the mould must be opened again, the layer of clay taken out of it, and the core thoroughly dried, and even burned, with a charcoal fire, or with straw; for if the least damp remain the cast will be blown to pieces when the hot metal comes in contact with it, in running it into the mould, and the workmen employed about the work be maimed or killed by the dispersion of the heated bronze. After the core, &c. has been properly dried and is deemed ready for the work, it should be laid in the mould, and supported in its place by short rods of bronze, which should run through the mould into the core. All being so far advanced, the mould should be clad and bound round with iron, of strength proportionate to the size of the work to be cast; after which the mould should be laid in a situation for running in the metals, and must be supported for that purpose by bricks, &c. Great care should be taken that every part be perfectly dried before any metal be run into the mould, or, as has been before observed, the most fatal consequences will arise to those who may be about the work. A channel must be made from the furnace in which the melted metal is, in order to its running to the principal jet of the mould, and with a descent to promote its flowing rapidly. The jets, furnace, &c. &c. are all contrived, as has been before described, for casting figures in brass.

Founding of Iron.—Owing to the immense demand for cast iron in most of our great public works, such as bridges, rail-roads, columns, girders, fences, gas and water pipes, house-building, framing of machinery, and innumerable objects of less magnitude, iron founding has become one of the most interesting and important of our national manufactures. Wherever a foundry is to be formed, a dry situation should be selected for it, as dampness would totally prevent any thing being cast with tolerable accuracy, besides rendering the founding, in such places, dangerous to the workmen employed. The floor of a building for this

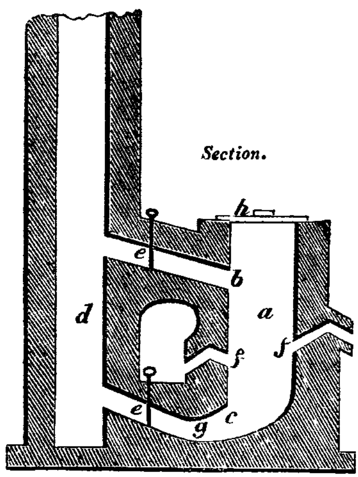
business should be about ten feet deep, and composed of a kind of loamy sand; and if the place selected does not afford this convenience naturally, the ground must be made hollow, and such sand brought to fill up the excavation. This loamy sand is for the purpose of burying large moulds beneath its surface, so that the metal may be conveyed to them by channels or soughs hollowed out of the sand, and through which it runs from the furnace to the mould to be cast. A foundry, or casting-house, is provided with as many air or reverberating furnaces, in addition to the blast furnaces, as is required for the extent of the works to be founded at it; an air or reverberating furnace is only used occasionally, either when the metal contained in the blast furnace is not sufficient, or when the quality made in it is not proper for the work about to be cast. The difference in the qualities of the metals arises from their containing too much or too little carbon, and this is corrected by the founder, who mixes them with better or worse metal till they are rendered fit for the purpose required. Cupolas, as they are called, are also wanted in a foundry, and are similar to the blast furnace, except being of somewhat smaller capacity; they are used to melt small quantities of metal when it is wanted in haste, as the reverberatory or blast furnaces will take more time in filling the charge of metal than the cupola does, by reason of their being of larger capacity; but the founding by cupolas requires more machinery, from which circumstance it is not so well adapted to answer the purpose of the founder as the employment of a reverberatory or blast furnace. A much greater stock of flasks and other implements is wanted to make the moulds with, than is required by the caster who performs his work by means of either of the other furnaces; these kinds of furnaces are always in use at large foundries, as at such places can be employed the whole charge of metal they are capable of containing. In a foundry worked by a blast furnace, a pit is sunk at a convenient distance from it, and the moulds for all large articles, such as pipes, &c. are placed vertically in it, within reach of the crane, that they may be raised or lowered in the pit. The metal is conveyed from the furnace by a gutter or trough made in the floor of the foundry, and a small iron trough, filled with sand, conducts the fluid metal into the moulds. This method of performing foundings at large works is an improvement on the old one, (which consisted in burying the pattern in sand,) and which has caused a great saving in labour and time. The flasks for this method of casting are founded of iron. It is now a practice at most of our large foundries to substitute sand for loam castings, in cases in which there are a great number of articles of the same kind to be cast, so that the expense of the flasks becomes an object of no great importance. When it happens that the articles are intricate, the sand is wetted so much as to render it sufficiently adhesive to make it mould, and receive the form of the pattern completely; after this is done, it is necessary to dry the mould, to prevent accidents by the explosion of the hot metal when running the cast; for this purpose stoves are used in which an equal and moderate degree of temperature is produced, and of a capacity adequate to contain a good number of the patterns. The moulds, when ready to be dried, are placed upon a carriage adapted to the purpose, and on which they are arranged and conveyed to the oven; and when dry, which generally happens in about half an hour, they are withdrawn, and a new set placed upon the carriage. Every foundry should be provided with one or more cranes, so placed as to be easily got at when it is required to raise, lower, or remove, any large piece of casting. The moulding of large pieces of cast-iron, when they are required to be hollow, is made in loam, and consists in laying down an iron ring upon the ground, of the diameter of the proposed calibre of the work to be cast, and which has a rod of iron in its centre; after this is done, bricks, clay, and wet loam are mixed together, and built up within the ring and round the iron rod, of somewhat less diameter than the cylinder about to be cast, and for which this is to form the core. The whole, when built, is bound round with iron hoops to protect it, and a fire is made inside to dry it; and when properly dried, a coating of loam is spread all over and smoothed; this coat fills up and makes it the proper size for the inside of the cylinder, and is called the core of the mould. Another cylinder is built and plastered in the same manner,

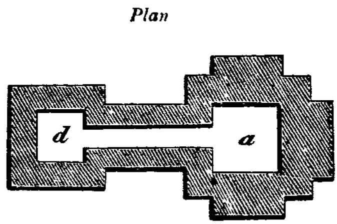
but without hoops, whose diameter is the same as the outside of the cylinder to be founded. When this is finished, it is covered over with charcoal dust, or ground charcoal, which is mixed up with water-like paint, and laid on with a brush; and a thin coating of loam, mixed up with hair, is then laid over the charcoal, previously spread upon the inner cylinder. When all these are quite dry, a man gets into the cylinder, and with a picker pulls away from the core the bricks, and then with a trowel cuts away also the loam, leaving the inside of the external cylinder, which is called the mould, quite smooth; this part of the work is effected by the coat of charcoal, which prevents the two coats of loam from adhering together. While this is doing, a deep pit is dug, and into this the core is let down by a crane; when this is done, the mould is lowered over the core; as soon as the adjustment is perfected, sand is thrown in and rammed round about it, to about the half of its height; after which a flat cover of dried loam is put on the top of the mould and core, and pieces of rounded wood are put into the holes, which had been before made for pouring in the metal. The plugs which keep open these holes are carefully taken out, and small channels prepared for the metal to run through from the furnace. Before the metal is run into the mould, the latter should be carefully examined, to ascertain that it is quite dry, and in other respects in a perfect condition to receive the metal. Sand, or open casting, is used for such articles as will allow of cutting into two pieces, or even more, the models of which are indented in the sand, and the metal is run in between flasks.

A patent for an improved mode of casting metallic cylinders was taken out in 1826 by Mr. William Church, of Birmingham, the object of which was to produce perfectly sound castings of uniform solidity. The process consists in exhausting the air from the moulds by means of an air-pump, and afterwards in forcing the fluid metal, from an air-tight reservoir beneath, upwards into the mould by the aid of a condensing pump. As the apparatus for this purpose may be constructed in a variety of ways, and be adapted to the description of articles to be cast, the patentee has described only one arrangement, which he adopts and recommends for the purpose of casting large cylinders, rollers, cannon, &c. The mould prepared for casting is enclosed in a cast-iron air-tight casing, and suspended in a vertical position, by means of chains, to the jib of an ordinary crane, over the vessel containing the fluid metal; to the lower end of the mould, an earthen tube (the materials similar to the crucible ware,) descends and forms the channel for conveying the metal upwards into the mould at the proper period of time; this earthen pipe is covered with a cap at its lower extremity, which is luted to it so as to be air-tight, and the material and thickness of the cap is such that it will melt a short time after being immersed in the fluid metal. As soon as the metal has arrived at the proper temperature the suspended mould, with its appendage, as before mentioned, is lowered by means of the crane, so that the earthen tube is immersed into the liquid metal in the chest beneath; this metal chest is then closed air-tight with a flange fixed on the upper part of the earthen tube, by proper contrivances for that purpose, such as a conical rim, an elastic metal hoop and luting; the perfect closing of which is effected by the pressure of the mould in its descent to its seat on the top of the metal chest. The apparatus so far prepared is next connected by short pipes with union joints, to pipes leading from an air-pump of large dimensions, which both exhausts and condenses. First, the air is exhausted from the mould, and from above the surface of the melted metal in the chest; by this time the cap of metal at the lower end of the earthen tube becomes fused, the fluid metal ascends that tube, and is then forced by the condensing operation of the air-pump into the mould above, which, being previously exhausted, the metal is uniformly pressed into every cavity. As the vacuum in the mould is of course imperfect, from the previous exhausting operation, and the remaining portion of air becomes condensed by the rising of the metal, to prevent any ill effects from its pressure, a stop cock, communicating with the exhausting end of the air-pump, is opened, by which it is withdrawn. For the purpose of rapidly cooling the mould after being filled with the liquid metal, the cast-iron mould case is surrounded with an outer case or jacket, with

a vacant space between, which is charged with cold water whenever desired, as in some castings this application must be of great utility in hardening their surfaces.

In 1825 a patent was taken out by Messrs. White and Sowerby for an air furnace for melting iron, for the use of founders, in which the requisite degree of heat is obtained without the necessity of resorting to mechanical aid, but simply by the production of natural currents of air through lateral openings or passages, with the further advantage of causing a body of flame to be conducted over that portion of the metal lying in a fluid state at the bottom of the furnace, by which it is kept from solidifying prior to the whole contents being discharged. On these principles the patentees state that the furnaces may be made square, round, oval, octagonal, or any other convenient form, with passages for the admission of atmospheric air in various parts and in different directions, according as they may be required to direct the heat. The annexed figures are intended to illustrate one convenient mode of carrying it into effect.





a represents the body of the furnace, in which the coke and metal is deposited; *b* and *c* are flues leading from the same into the vertical chimney *d;* the capacity or depth of the flues is regulated by dampers *e e; f f* show the situation of two of the lateral air chambers, (of which there may be any number;) one of these is shown as opening into the outside of the structure, and the other into an open archway or passage between the chimney and the body of the furnace; a man hole, for clearing out the bottom or bed of the furnace whenever required, is situated at *g*. To set the furnace to work, the cover *h* is removed, and coke or other fuel thrown in, which may be lighted, if required, at either of the air passages *f f;* when the heat has been raised to the proper degree for the fusion of the iron, the metal and coke are thrown in alternately, in such quantities and proportions as may be required for the casting, when the furnace is again to be closed by the cover *h*. When the whole of the metal is reduced to the fluid state, it is run off from the bed by means of a tap hole in the lower part. By the arrangement of the furnace, it will be perceived that a body of flame is made to operate upwards in melting the metal, and another takes a downward course, passing over the bed of the furnace, preserving that portion of the metal which has been already melted, and lying upon it, in a fluid state, until the whole contents of the furnace are melted.

The founding of iron cannon is conducted in a similar manner to other castings; the pattern is moulded in the sand, and the metal run into the mould

through a gutter. Small guns are moulded on tables, one half of the mould being formed on one table, and its counterpart on another; they are fitted together by pins, and screwed up by nuts and bolts to keep them firm together whilst the hot metal is run in. About fifty years ago cannons were cast with a hollow cavity for the bore, which was afterwards enlarged and cleaned out by a machine adapted to the purpose. Guns are now invariably cast solid, owing to the difficulty of getting them perfectly sound by that mode of casting, being more or less spongy in some parts, which the subsequent turning did not wholly remove. For the method of boring and turning great guns, see the article CANNON.

The manner of casting bells is similar to that of statues, except that bell-metal contains about one-fifth of tin to four-fifths of copper, while the metal of statues contains no tin. The dimensions of the core and wax in modelling a bell, if it be one of a ring of several, must be formed on a kind of scale or diapason, which will give the height, aperture, and thickness of the shell necessary to the several tones required. Our proportions of bells consist in making the diameter fifteen times as thick as the brim, and its length twelve times. See the article BELL, under its initial letter.

We now come to the description of that department of the foundry art which must be regarded as the most valuable and important when its effects in ameliorating our condition as intellectual beings is considered: we allude to the art of founding type. This invention is supposed to have originated at Mentz, in the early part of the fourteenth century, when types were carved out of wood. Some time afterwards they were cut of metal, and one Laurentius was honoured as the inventor of this improvement, which, however trifling it may appear as an advance in any mechanic art, proved to be of vast importance in its result. The art of founding or casting types quickly succeeded, which appears to have had its origin also in Germany, as we find they were first introduced into Holland from Strasbourg. By the mercantile activity of the Dutch at this period the new metal type was rapidly dispersed into all the capital cities of Europe. The earliest use of them in this country was at Oxford, in 1468, when a book was printed there by one Bouchier. In 1471 Caxton, who had studied the art in Holland and the Low Countries, established several printing presses in this country. The art of reading, which, but a short time before, was chiefly confined to a portion of the clergy and nobles, was soon extended to the other gradations of society; and the ability to read was no longer considered the highest climax and finish of an education, but was made the first step to it, by the introduction of printed books into every school and seminary. As the rudiments of education became improved, books became rapidly multiplied, printing encouraged, and ever since a progressive improvement has been gradually developing itself. Until the seventeenth century types continued to be cast with very few improvements, excepting such as arose from alterations in the form of the letters. Caslon set up a foundry in 1720, and succeeded in making several improvements, to which some valuable additions were added by Baskerville, of Birmingham. Messrs. Fry and Son's foundry was established in 1764 In 1770 Mr. Jackson cut some very extraordinary and beautiful types, by a mould and matrix, which were previously cast in sand. Mr. V. Figgins, in 1792, produced some beautiful types for the Persian, Greek, and Hebrew characters, never before attempted in this country. In 1800 Messrs. Caslon and Catherwood set about recutting and improving the whole business; and the superior taste and elegance displayed in their manufacture occasioned a spirit of rivalry in the other type founders, particularly Messrs. Fry, Figgins, and Thorne, who exerted themselves individually so as not to be surpassed by their competitors; the effect of which has been the production of types of that high degree of excellence, which marks the character of all our books printed since that period. The preparation of the moulds and matrices for the purpose of casting the letters requires the utmost precision of workmanship; the matrix itself is simply a piece of copper or brass, about an inch and a half long, and of a thickness in proportion to the size of the letter to be cast. In this piece of metal is sunk the face of the letter, by means of a steel letter-punch. These

punches being made with every size and kind of letter, are, of course, very numerous; and the making of them, requiring the utmost nicety of execution, necessarily forms a branch of the type-founder's business of considerable importance. There are about twenty different sizes of each kind of type in general use, all of which are cast in moulds and matrices, besides several larger sorts, which are cast from patterns in sand. The following table gives the designation of the twenty sizes alluded to, and the spaces they occupy in printing. They are sold to the printer by the pound, at prices varying from two to thirteen shillings, according to their size:—

	Lines to each foot.		Lines to each foot.
Diamond type	204	Great Primer	51
Pearl	178	Paragon	44½
Nonpareil	143	Double Pica	41½
Minion	128	Two-line Pica	35¼
Brevier	112½	Two-line English	32
Bourgeois	102	Two-line Great Primer	25½
Long Primer	89	Two-line Double Pica	20¾
Small Pica	83	Canon	18
Pica	71½	Four-line Pica	17¾
English	64	Five-line Pica	14¼

When the moulds and the set of matrices are duly prepared, they are brought to the furnace, and consigned to the hands of the caster. The furnace is built of bricks upright, with four square sides; the stove for the fuel is at the top, with a round hole made through it, to receive the pan which holds the metal. In a large foundry there are several of these kinds of furnaces. The caster begins his work by taking the mould in his left hand, and with his right puts back a spring, which keeps the matrix close up to the face of the mould, and then with a small ladle adapted to the size of the work, he dips out of the pan over the furnace a sufficient quantity of fluid metal to fill the mould, and at the same instant that he turns the metal from out of the ladle into the mouth of it, he throws up his hand, in which is held the mould, with a sudden jerk or shake, and by this movement forces the melted metal down into the face of the matrix. In this operation great expertness is necessary. After the letter is thus cast, he relieves the spring, and takes the face of the type from the matrix, which is done by pressing the thumb of the right hand against the top of the matrix; he then picks out the type, and goes on with the casting. Thus, in the casting of every single type, there are several distinct operations to be performed; yet, owing to the admirable adaptation of the apparatus to the purpose, an expert caster can, on an average, cast from six to seven thousand letters a day. When the workman has cast as many types of the same letter as are required, he exchanges the matrix for one containing another letter, and proceeds as before. The types, after being cast, are received by the "break-off boy," who takes off the break or rim of the letter;—this operation is performed with so much expedition that some boys will break off from 5 to 6000 in an hour. From the break-off boy the new types are put into the hands of a "rubber," to have their rag or beard removed, which is effected by rubbing them over a stone. A great number of boys are employed in a type foundry besides those mentioned in the various processes of the manufacture,—such as "kerners," "setters up," "dressers," &c., their operations being directed to the perfecting of the form and finishing of the type,—a circumstantial account of which our limited space will not admit of. The metal of the type-founder consists of lead and antimony fused together, the proportions of which are regulated by the size of the type to be cast. The smallest sized types require the hardest metal, the alloy for which is 25 of the regulus of antimony to 75 of lead, in 100 parts; in the larger sizes the proportions are varied accordingly, down to 15 parts of antimony to 85 of lead. The usual method of casting the larger kind of types, is by cutting the letter through a plate of brass, and afterwards riveting to it a back to form a matrix; these moulds are hung up, and the liquid metal

simply poured into them; the very large letters are cast in open sand, in the usual way of brass casting. The moulds and matrices of the type-founder are extremely valuable, and are therefore secured every night in strong rooms of iron or stone.

By the common method of type-founding, which we have now briefly described, only a single letter is cast at a time, and the operation has been nearly the same for upwards of seventy years; a scheme was, however, set on foot by a Mr. White, about seventeen years ago, to enable the founder to cast a great number of letters at one time—thirty or more; but it was not carried into practice by any of the founders. About the same time a Monsieur Didot, assisted by Mr. Donkin the engineer, constructed a machine for a similar purpose, which was also intended to perform all the operations of the work by the assistance of a boy only.

The invention which we have now to describe is an improvement by Monsieur Didot upon his former highly ingenious machine, now rendered capable of casting 200 types at once, and to repeat the operation two or three times in a

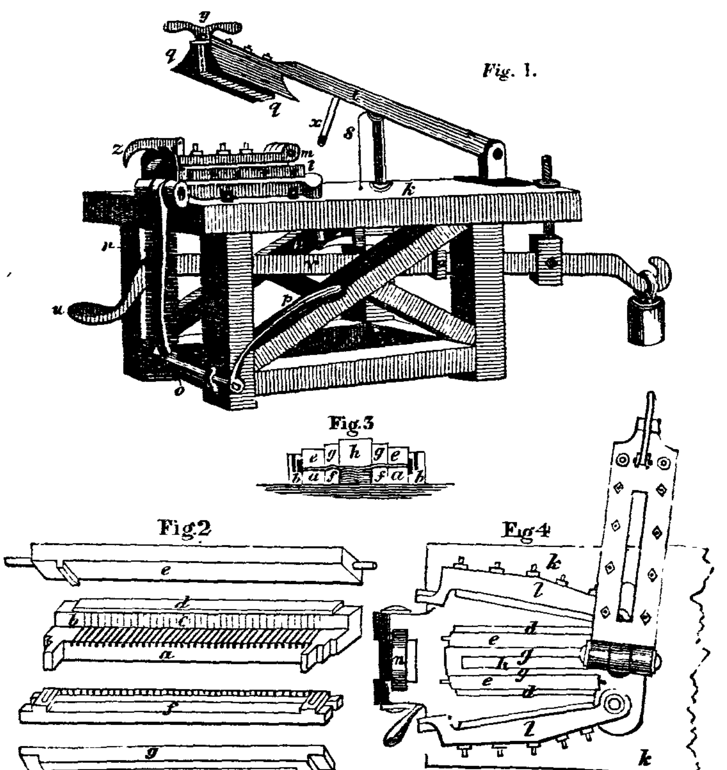


Fig. 1. Fig. 3 Fig. 2 Fig. 4

minute. A patent for this country was taken out by Mr. John Louis Pouchée, who a few years ago established a type-foundry in Little Queen-street, Holborn, where the machinery is at present in full and successful operation. The great number of drawings which accompany the specification of this patent obliges us to select such portions only as will best give a just idea of its nature and construction; and we have for the same reason thrown the side views into perspective,

which exhibits the machine entire, as at *Fig.* 1. *Fig.* 3 represents one side of the mould separated into its component parts. *Fig.* 2 is a section of the several bars composing both sides of the mould. *Fig.* 4 exhibits a plan of the same, fitted into and encompassed by a frame of iron, a horizontal and perspective view of which is given at *Fig.* 1. The same letters refer to the same parts in each of the figures. *a* (*Fig.* 3) is a steel bar, with horizontal grooves, in which are formed the bodies of the types; *b b* is the bar which holds the matrices *c c*, each of which is arranged opposite to its respective groove in the bar *a*, to which it is screwed fast; the bar *d* is then screwed down to the bar *b*, which holds the matrices *c c* firmly in their places. The bar *e* is next laid upon the bar *a*, which covers the grooves, and forms the upper sides of the square recesses, shown also at *e e*, *Fig.* 4. *f* is the break-bar, and is placed in front of the bar *a*; a series of small nicks or openings are made in this bar, through which the fluid metal passes into the grooves and matrices, where the body and letters of the type are cast; the grooves are closed by the spaces between the nicks of the break-bar coming against them, and forming the feet of the types. The bar *g* is laid upon the break-bar as a cover to it, and the whole six bars thus combined form one side, or one half, of a pair of moulds, shown in section, *Fig.* 3. This section likewise exhibits the form of the apertures through which the fluid metal has to pass into the grooves and matrices; *h* is a receptacle between the moulds for the fluid metal, previous to its being forced into them, as we shall presently describe. In preparing the moulds for casting, the several bars composing them are connected together as before mentioned, and laid upon a solid metallic bed upon the table *k k*, as shown at *Fig.* 4: the sides of the iron frame *l l*, which turn upon joints, are then brought to bear sideways against the moulds; the top piece *m*, which also turns upon a joint, is brought down over the mould bars, which it firmly secures by bringing the looped part of the swinging lever *n*, shown at *Fig.* 1, over the end of the top piece *m*, which is effected by the aid of the hand lever *p* forcing the tongue *o* against the lower end of the swinging lever, when the latch *z* falls and makes all fast. Thus prepared, a sufficient quantity of the fluid metal is poured out of a ladle into the receptacle between the moulds; a trigger at *r* is then pulled, when a string connected to it draws back a bolt or catch *s*, which supports the long lever *t*, and allows it to fall with the rammer *q* into the receptacle, which "drives with considerable force the fluid metal from thence into the moulds and matrices." On each side of the rammer *q* is fixed "a guard or housing, to prevent the liquid metal from being splashed over the operator." In order to withdraw the types from the moulds, the workman places his foot upon the step *u*, when the compound lever *v* acts upon the pin *w*, under the leg *z*, and forces out the rammer from between the moulds, which is then lifted up by the workman, until it has passed the catch *s*, which supports it in the position shown in the figure. The mould is now opened by throwing up the hasp *x*; the swinging lever *n* then releases the end of the top piece, and allows the frame to be opened, and the moulds to be removed to a table, where the bars which compose it are placed under cramps, and separated by means of wrenches: the types are then removed, and undergo the operations of dressing, &c. as mentioned in the early part of our subject.

FOUNT, or Font, among Printers, a set of types, sorted for use, that includes running letters, large and small capitals, single letters, double letters, points, lines, numerals, &c.; as a fount of english, pica, bourgeois, &c. A common fount consists of 100,000 characters. See Printing and Type-Founding.

FRACTION, in Arithmetic and Algebra, is a part or parts of something considered as a unit or integer. Fractions are distinguished into vulgar fractions and decimal fractions. Vulgar fractions consist of two parts or quantities written one over the other, thus $\frac{2}{3}$, $\frac{3}{4}$, &c.; the quantity above the line is called the numerator, and that below the line the denominator. Decimal fractions are written with a dot to the left hand of the series, thus, ·1, ·02, ·003, and may be considered, and are read, as vulgar fractions, whose denominator is always 1, with as many cyphers annexed as there are figures in the decimal, and the

decimal will then be the numerator; thus, ·1, ·02. ·003, are to be read as $\frac{1}{10}$, $\frac{2}{100}$, $\frac{3}{1000}$.

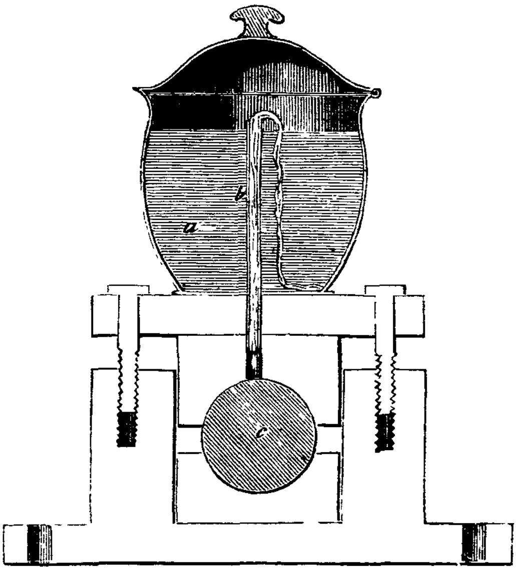
FRANKINCENSE, or OLIBANUM, is a gum resin, the product of the *Junipus lycia* of Linnæus, brought from Turkey and the East Indies, usually in drops or tears. The best sort is of a yellowish white colour, solid, hard, and brittle. When chewed it impresses an unpleasant bitter taste; laid on burning coals it yields an agreeable odour, and is for this reason much used by the Catholics, the Jews, and various idolatrous nations, in their religious ceremonies, the powerful perfume having a tendency to prevent the communication of infection amongst a dirty people, and of moderating the disgust created by the slaughter of the victims of the sacrifices.

FREEZING. See CONGELATION, FROST, and CHEMISTRY.

FRICTION, in Mechanics, the rubbing of the parts of engines or machines against each other, by which means a great part of their effect is destroyed. A body upon a horizontal plane should be capable of being moved by the smallest application of force; but this is not the case, and the principal causes which render a greater or less application of force necessary are, first, the roughness of the contiguous surfaces; secondly, the irregularity of figure, which arises either from imperfect workmanship or the penetration of one body by another; thirdly, an adhesion or attraction, which is more or less powerful according to the nature of the bodies in question; and fourthly, the interposition of extraneous bodies, as dust, moisture, &c. Innumerable experiments have been made to determine the amount of friction or obstruction which is produced in particular circumstances; but the results of apparently similar experiments which have been made by different experimenters do not agree, nor is it likely they should, since the least difference of smoothness or polish, or of hardness, or, in short, of any of the concurring circumstances, produces a different result: hence no certain and determinate rules can be laid down on the subject of friction. Mr. Vince, who has done much on this subject, infers, first, that friction is a uniformly retarding force in hard bodies, not subject to alteration by the velocity except when the body is covered with cloth, woollen, &c., and in this case the friction increases slightly with the velocity; secondly, friction increases in a rather less ratio than the weight of bodies; the rate of increase, however, is various in different bodies, nor is it sufficiently determined for any one body what proportion the increase of friction bears to the increase of weight. The smallest surface, at least up to a certain point, has the least friction, the weight being the same; but the ratio of friction to the surface is not yet accurately known. The friction of mechanical engines not only diminishes the effect, or, which is the same thing, occasions a loss of power, but is attended with the corrosion and wear of the principal parts of the machine, besides producing a considerable degree of heat, and even actual fire; it is therefore of great importance in mechanics to contrive means capable of diminishing, if not quite removing, the effect of friction.

The methods of obtaining the important object of diminishing friction are of two sorts, viz. either by the interposition of unctuous or oily substances between the contiguous moving parts, or by particular mechanical arrangements. Olive oil is the best and perhaps the only substance that can be used in delicate work, as clocks and watches, when metal works against metal; but in large works the oil is liable to drain off unless some method be adopted to confine it. The best contrivance with which we are acquainted, for preventing the waste of oil, and for keeping gudgeons or axes properly supplied with it, is Barton's Patent Lubricator, a section of which is shown in the accompanying engraving, with the manner of applying it to the shafts of mill work. *a* shows a section of a metallic vessel filled with oil, and closed by a lid to prevent the admission of dust or other adventitious matter; *b* is a small tube rising to nearly the top of the vessel, and with the lower part extending an inch or two below it, and inserted into an aperture made through the plummer block, directly over the shaft *c*, shown also in section; through this tube a few threads of woollen yarn are drawn, which reach to the bottom of the vessel, and conduct the oil by capillary attraction, as a syphon, in minute but regular quantities to the shaft

or gudgeon; the whole of the oil in the vessel is thus carried over, entirely free from dust or other impurities, and in the precise quantity required, which is easily regulated by the number of threads. It must be obvious that the economy of



this contrivance is very considerable; that machinery, where it is applied, will run with less friction, last longer, and require less power. Since the above cut was executed, Mr. Barton has greatly improved these lubricators, and materially extended their utility. From some experiments which have been made, it appears that when the strain is very great the solid unguents appear to be more effectual in diminishing friction than oils, and in this case tallow or swine's grease is generally employed. The celebrated "Anti-Attrition Composition" is simply a mixture of hog's lard and plumbago, in the proportion of four parts of the former to one of the latter. In launching ships the "ways" are smeared with soft soap. The mechanical contrivances for the diminution of friction consist either in avoiding the contact of such bodies as produce much friction, or by substituting a *rolling* for a *sliding* motion, as far as it may be practicable. As an instance of the first method we may notice that in mill work, the wooden axes of large wheels terminate in iron gudgeons, turning generally in brass bearings, which produces less friction than wood upon wood; and as the iron gudgeon can be made of smaller diameter than wooden ones of the same strength, the friction is also diminished from that cause in nearly the same ratio. The conversion of a sliding motion into a rolling motion is effected by interposing cylindrical bodies between the moving parts of machines, which, according to their size and arrangement, are denominated rollers, wheels, and (although improperly) friction rollers. In order to understand the nature of rollers, and the advantages attending their use, it must be considered that when one body is dragged over the surface of another, the inequalities of the surfaces of both bodies meet and oppose each other, which is the principal cause of friction or obstruction; but when one body, such as a cask, a cylinder, or a ball, is rolled upon another body, the surface of the roller does not rub upon the latter, but its parts are successively applied to or laid upon it, and are afterwards lifted up from it; therefore, in rolling, the principal cause of friction is avoided, and other advantages also

obtained: thus, in mounting a carriage upon wheels, instead of placing it upon skids or a sledge, the only friction arising from the sliding of one part over another is that which takes place between the axle and the box in which it works. The diminution of friction from this cause will be in the proportion of the diameter of the wheel to that of the axle, and it is further diminished by the friction being that of metal sliding upon metal, which offers much less resistance than the best made road could be brought to do, and also that the friction may be further reduced by means of lubricating substances. When the sliding motion in machinery is not in a rectilinear direction, but arises from the revolution of axes in their bearings, a great part of it may be converted into a rolling motion by supporting the axes upon the peripheries of four wheels instead of the usual fixed bearings; an instance of this is seen in the elegant machine invented by Mr. Atwood for illustrating the laws by which the descent of falling bodies is regulated. But although friction detracts from the effect of machines, and it is therefore generally an object to reduce it to the utmost, yet the action of some parts of machinery depends upon friction, as in the case of the brake of a crane or the drag of a coach. For light machinery, also, wheels are sometimes made to turn by contact, by simply covering their periphery with buff leather, the resistance of the work not being sufficient to overcome the friction between the two surfaces.

FRIT. The matter or ingredients of which glass is made, after they have been calcined in a furnace. These ingredients are chiefly soda and flint, or silicious sand.

FRIZING OF CLOTH. A term applied to the forming the nap of woollen cloth into a number of little hard burs or prominences covering almost the whole of the ground. It is commonly performed by a machine or mill worked by water or horses; the structure is as follows:—The principal parts are the frizer, the frizing table, and the drawer or beam; the two first are two equal planks or boards, each about ten feet long and fifteen inches broad, differing only in this, that the frizing table is covered with a coarse kind of woollen stuff, with a rough sturdy nap, and the frizer is incrustated with a kind of cement, composed of glue, gum arabic, and a yellow sand, with a little aqua vitæ, or urine. The beam or drawer, thus called because it draws the stuff from between the frizing table and the frizer, is a wooden table, beset all over with little, fine, short points or ends of wire, like those of cards used in carding of wool. The cloth, being stretched along the frizing table with that side uppermost which is to be frized, is drawn slowly over the table by the beam or drawer, whilst the frizer, which is suspended at such a distance from the table as merely to allow the cloth to pass between the two surfaces, and which has a very slow semicircular motion, meeting the long hairs or naps of the cloth, twists or rolls them into little nobs or burs; the workman supplying and stretching the cloth at one end of the table as fast as it is drawn forward by the drawer at the other end.

FROST. Such a state of the atmosphere as causes the congelation or freezing of water or other fluids into ice. In the more northern parts of the world even solid bodies are affected by frost, though this is only or chiefly in consequence of the moisture they contain, which being frozen into ice, and so expanding, as water is known to do when frozen, it bursts and rends any thing in which it is contained, as plants, trees, stones, and large rocks. Many fluids expand by frost, as water, which expands about one tenth part, for which reason ice floats in water; but others again contract, as quicksilver, and thence frozen quicksilver sinks in the fluid metal.

FRUSTRUM, in Geometry, is the part of a solid next the base left by cutting off the top or segment by a plane parallel to the base, as the frustrum of a cone, a pyramid, a conoid, or of a sphere, which is any part comprehended between two parallel circular sections; and the middle frustrum of a sphere is that, whose ends are equal circles.

FUEL. Those substances which receive and retain fire until they are wholly or partially consumed. Dr. Black divided fuel into five classes. The first comprehends the fluid inflammable bodies; the second, peat or turf; the third,

charcoal of wood; the fourth, pit coal charred; and the fifth, wood or pit coal in a crude state, and capable of yielding a copious and bright flame. The fluid inflammables are considered as distinct from the solid on this account—that they are capable of burning upon a wick, and become in this way the most manageable sources of heat, though, on account of their price, they are never employed for producing it in great quantities, and are only used when a gentle or small degree of heat is sufficient. The species which belong to this class are alcohol and the different oils. The first of these, alcohol, when pure and free of water, is as convenient and manageable a fuel for producing moderate heats as can be desired; its flame is perfectly clean and free from any kind of soot; it can easily be made to burn slower or faster, and to produce less or more heat, by changing the size or number of wicks upon which it burns;—for as long as these are fed with spirit in a proper manner, they continue to yield flame of precisely the same strength. The cotton, or other materials of which the wick is composed, is not scorched or consumed in the least, because the spirit with which it is constantly soaked is incapable of becoming hotter than 174° Fahr.; it is only the vapour which arises from it that is hotter, and this, too, in the parts most remote from the wick, and where only the combustion is going on, in consequence of communication and contact with the air. At the same time, as the alcohol is totally volatile it does not leave any fixed matter, which, by being accumulated on the wick, might render it foul and fill up its pores; the wick, therefore, continues to imbibe the spirit as freely, after some time, as it did at the first. These are the qualities of alcohol as a fuel: but these qualities belong only to a spirit that is very pure. If it be weak, and contain water, the water does not evaporate so fast from the wick as the more spirituous part, and the wick becomes, after some time, so much soaked with water that it does not imbibe the spirit properly: the flame becomes much weaker, or is altogether extinguished. When alcohol is used as a fuel, therefore, it ought to be made as strong or as free from water as possible. Oils, though capable of burning in a similar manner to alcohol, are not so convenient in many respects; the soot which they emit accumulates at the bottom of the vessel exposed to it, and checks the transmission of heat. By employing numerous very small wicks, or the argand burners, we may chiefly prevent the formation and deposit of soot; but the wicks become scorched or charred, and are soon rendered incapable of absorbing the oil so fast as before. Attempts have been made to obviate this difficulty by making wicks of incombustible matter, as asbestos or wire; nevertheless, as the oil does not totally evaporate, a small quantity of gross carbonaceous matter fixes itself to the wicks which, by degrees, absorb less and less of the fluid, until they become quite useless.

The second class of fuel mentioned, peat or turf, is so spongy, that, compared with the more solid fuels, it is unfit to be employed for producing strong heats. It is too bulky for this; we cannot put into a furnace at a time a quantity that corresponds with the quick consumption that must necessarily go on when the heat is violent. There is, no doubt, a great difference in this respect among different kinds of peat, but this is the general character of it; however, when we desire to produce and keep up by means of cheap fuel an extremely mild uniform heat, we can hardly use any thing better than peat; but it is best to have it previously charred or burnt to a black coal. When prepared in this manner it is capable of being made to burn more slowly and gently, or will bear, without being extinguished altogether, a greater diminution of the quantity of air with which it is supplied than any other of the solid fuels. According to Clement and Desormes peat affords only about one-fifth of the heat that is given out by an equal weight of charcoal. Mr. Tredgold states, that the weight of a cubic foot varies from 44 to 70 pounds, and that the dense varieties afford about 40 per cent. of charcoal; the other varieties nearly in proportion to their density.

The third class mentioned, the charcoal of wood, is capable of affording an intense heat. Mr. Dalton, by heating water, obtained a result equivalent to melting 40 lbs. of ice with 1 lb. of charcoal. Dr. Crawford's experiments give 69 lbs. of ice melted by 1 lb. of charcoal. Lavoisier, Clement, and Desormes, about 95 lbs.; and Hassenfratz, 92 lbs. Mr. Tredgold considers 47 lbs. of ice

melted to be the real average effect of 1 lb. of charcoal: a cubic foot weighs about 15 lbs.

The fourth mentioned class of fuel, pit coal charred or coke, possesses similar properties to wood charcoal, although it is a much stronger fuel,—that is, it contains the combustible matter in a more condensed form; it is, therefore, consumed much more slowly, and is better adapted for long-continued intense heats. It has, however, a defect, from which wood charcoal is free; it leaves dense ashes in the grate, which in time collect in such quantity as to obstruct the passage of the air; and when the heat is intense, these ashes vitrify into a tenacious substance, which clogs the furnace. It is preferable to wood coal for melting metals, as affording a greater quantity of heat before it is consumed, and at a less expense.

The fifth class of fuel, according to Dr. Black, is wood and crude coal; these differ from their charcoals in affording copious and bright flames when plenty of air is admitted to them. If but little air be admitted sooty vapours are given out without flame, and with greatly diminished heat. Wood and candle coal do, however, differ from each other so much, as respects their useful properties in manufacturing operations, that we deem it necessary here to drop the generalization of Dr. Black, and consider wood and coal, and the varieties of each, separately. First, as respects—

Wood: its effect in producing heat depends greatly on its state of dryness. Several experiments made by Count Rumford show the effect of dry wood to be much greater than that of unseasoned; the latter containing about one-third of its weight of water. The kind of wood is also a cause of some difference; lime-tree wood was found, by Count Rumford, to give out most heat in burning. With 1 lb. of dry pine-wood, the Count caused 20.10 lbs. of ice-cold water to boil. The same weight of dry beech made only 14.33 lbs. of ice-cold water to boil. A cubic foot of dry beech weighs about 49 lbs. By the experiments of Fossombroni, wood was found capable, by its combustion, to evaporate twice its weight of water, or to prepare two-thirds of its weight of salt. Rumford made the effect about one-third more than Fossombroni, owing, possibly, to superior management in the former. By an experiment made at the Opera House, in Paris, 160 lbs. of wood were found to be equal in effect to 58 lbs. of coke.

As respects coal, there is a considerable difference in the effects of the several varieties. The caking or binding coal with which London is supplied from the great coal fields in Northumberland and Durham, under the general name of Newcastle coal, is much esteemed, from its affording a great heat, and burning with a lively flame; but those of Wall's End are regarded as superior to the latter for domestic use, as they burn with a whiter and more brilliant flame, and do not cake so hard in the grate. The Tanfield Moor coals are preferred for forges and furnaces, as they burn slowly, and afford a strong and long continued heat. From the experiments of Mr. Watt, it appears that a bushel of Newcastle coal, which weighs about 84 lbs. is competent to convert from 8 to 12 cubic feet of water into steam, from the mean temperature of the atmosphere; and that a bushel of Swansea coal will produce the same effect. Dr. Black states, 7.91 lbs. of the best Newcastle coals will convert one cubic foot of water into steam capable of supporting the mean pressure of the atmosphere; and this statement appears perfectly to accord with the more extended experiments of Watt. Smeaton makes it require 11.4 lbs. of coal to produce the same result in steam; but Smeaton has omitted to state the kind of coal. If he employed the Staffordshire coal, there is no discrepancy, as will appear from the table of Mr. Tredgold's experiments and calculations, which we shall subsequently insert in this article. Mr. Tredgold found, that after the brickwork, &c. of the boiler of a steam-engine was warmed, a little less than 1 lb. of Wall's End coals would make a cubic foot of water boil, from the mean temperature of 52°. To produce the same effect with inferior coals a stronger draft and more time and attention are necessary. Splint coal, or hard coal, called by Kirwan slaty cannel coal, is regarded as equally valuable for many purposes as the Newcastle caking coal. It does not produce so much flame nor so much

smoke; it does not kindle so quickly, nor does it agglutinate, like caking coal. A large body of splint coal makes a strong and lasting fire. Cherry coal, or soft coal, readily catches fire, and burns with a clear yellow flame, giving out much heat, and the flame continues till nearly the whole coal is consumed. It burns away more rapidly than either caking or splint coal, and leaves a white ash; it is easily distinguished from caking coal by its not melting or becoming soft when heated; it makes a more agreeable fire, and does not require to be stirred. It requires care and management in an open grate, even to burn the small fragments which are made in breaking up the pieces to a fit size for the fire: hence the small coals are often mixed with clay, and made into balls. When these balls are dry, Mr. Gray says, they make an excellent addition to the fuel for an open fire, producing a very durable heat. Mr. Watt calculated that 112 lbs. of these coals produced the same effect in raising steam as 84 lbs. of the Newcastle coal.

The following table, by Mr. Tredgold, shows the comparative and real effect of the principal varieties of solid fuel in converting water into steam.

Kind of fuel.	Fraction of a pound that will heat one cubic foot of water one degree of Fahrenheit's scale.	Pounds of fuel that will convert one cubic foot of water into steam.
Newcastle, or caking coal	0.0075	8.40
Splint coal	0.0075	8.40
Staffordshire cherry coal .	0.0100	11.20
Wood (dry pine) . . .	0.0172	19.25
„ (dry beech) . .	0.0242	27.00
„ (dry oak) . . .	0.0265	30.00
Peat of good quality . .	0.0475	53.60
Charcoal	0.0095	10.60
Coke	0.0069	7.70
Charred peat	0.0205	23.00

Mr. S. F. Gray is of opinion that fire-balls, of the size of goose eggs, composed of coal and charcoal in powder, mixed with a due proportion of wet clay, and well dried, would make a much more cleanly and in all respects a pleasanter fire, than can be made with crude coals, and not more expensive. He states, that in Flanders and Germany the practice of making equal weights of clay and coals together, and forming them into cakes, is common, and that the labour of the preparation is amply repaid by the improvement of the fuel, the coals thus mixed burning much longer, and giving more heat, than when they are burnt in their crude state; that although clay is an incombustible body, the fact is certain that coals so mixed afford more heat. For the purpose of lighting a fire speedily, Mr. Gray recommends the formation of "kindling balls," composed of equal parts of coal, charcoal, and clay, the two former reduced to a fine powder, well mixed and kneaded with clay moistened with water, and then formed into balls of the size of hens' eggs, and thoroughly dried, which, he says, may be used with great advantage, instead of wood. These kindling balls, he further observes, may be made so inflammable as to take fire in an instant, and with the smallest spark, by dipping them in a solution of nitre, and then drying them again; if made of pure charcoal mixed with a solution of nitre, they would be still more inflammable. In situations where coals are scarce or dear we think that the mixtures recommended by Mr. Gray might be found convenient and economical; but when it is considered that the average price of coals in England is not more than a shilling for a hundred weight, we can hardly conceive it possible that the same weight of fire-balls, of the size of hens' eggs, could be manufactured for the sum mentioned. It would appear, from Mr. Gray's remarks, that he was not aware that several patents had previously been taken out for the very objects mentioned by that gentleman; and although the advantages of them may not be very apparent in most situations, there are doubtless many localities where it may be otherwise; for the latter reason we shall, therefore, insert a

brief notice of some of them. Mr. Sunderland's patent dated 1825, is for a fuel, in which gas-tar, clay, and refuse woody matter, are combined in various proportions, according to the degree of inflammability required. One part of gas-tar, one of clay, and two parts of any convenient woody matter, such as saw-dust, tanners' spent bark, dyers' refuse wood, or peat, burn extremely well. If equal parts of the tar, clay, and saw-dust be employed, they make a composition which burns vividly and with a brilliant flame. The materials are, of course, to be thoroughly mixed, made up into lumps, and dried either artificially or in the open air, preparatory to their being used as fuel. Messrs. Christie and Harper's patent, dated 1824, was for various mixtures of culm and stone coal (or anthracite) with bituminous or caking coal, depending upon the nature of the heat required; for the boiler furnaces of steam engines, where the bars are half an inch apart, the patentees state that one-fourth of the bituminous coal answers well for invigorating the other three-fourths. In 1800 Mr. Peter Devey had a patent for an improved artificial fuel, and the same gentleman, in 1821, had another patent for fuel balls, the particulars of which will be found in the specifications of their patents in the Inrolment offices in Chancery.

FULCRUM, in Mechanics, the prop or support upon which a lever turns.

FULLER'S EARTH. A soft, greyish brown, dense marl. When dry it is of a greyish ash-coloured brown, in all degrees, from very pale to almost black, and it has generally something of a greenish cast; it is of a compact texture, smooth to the touch, and does not stain the fingers. Thrown into water it makes no ebullition or hissing, but swells gradually in bulk, and falls into a fine soft powder. Fuller's earth is of great use in scouring cloths, stuffs, &c., imbibing all the grease and oil used in preparing and manufacturing the wool; but owing to the almost general use of soap for these purposes, it is not now in such request in this country as formerly. In England it is found chiefly in Hampshire, Bedfordshire, and Surrey; it consists of—

Silex	51.8
Alumine	25.0
Lime	3.3
Magnesia	0.7
Oxide of Iron	3.7
Water	15.5
	100.

FULLING. A process by which woollen cloths are divested of the oil they imbibe by the operation of carding, and the texture at the same time rendered much closer, firmer, and stronger. This process, also called milling, is performed by a mill, thence called a fulling mill, the machinery of which consists of a number of wooden stampers or beetles, working in a large trough by means of cams or wipers on the shaft of a water wheel. The cloths are laid in the trough, and a quantity of warm water, in which is put a portion of fuller's earth or soap, being poured upon it, it is subjected to the action of the stampers, the repeated blows of which cause the fibres to felt and combine more closely together. After a time it is taken out, and the grease and filth wrung therefrom, and again returned to the fulling mill, from which it is occasionally taken to be stretched, and to undo the plaits it has acquired in the trough. When it is sufficiently milled and brought to the quality and thickness desired, it is scoured in the trough in clear water until perfectly clean, after which it is hung upon tenter-hooks to dry.

FULMINATING POWDERS. A variety of chemical combinations, which explode, by the application of certain degrees of heat, with instantaneous combustion and prodigious noise. See DETONATING POWDERS.

FUMIGATION. A process for destroying contagious miasmata or effluvia, by the fumes of various substances. The most efficacious substance for this purpose is chlorine, which may be readily applied in the state of gas by placing in the apartment to be fumigated an earthen pan, containing sea salt and black oxide of manganese, and pouring dilute oil of vitriol upon the mixture; but a

solution of chloride of lime is generally preferred. Next to chlorine in efficiency is the vapour of nitric acid; and, lastly, of muriatic acid; but the fumes of heated vinegar, burning sulphur, or exploded gunpowder, deserve little confidence.

FUNNEL. A conical or bell-mouthed instrument with a narrow tube, for facilitating the transferring of liquids or small substances from one vessel to another. Any pipe or passage is sometimes called by this name, in particular the small shaft or tube of a flue.

FUR, in Commerce, signifies the skins of several species of animals, dressed in alum, with the hair on, and used for the purposes of dress. The kinds mostly made use of are those of the ermine, sable, beaver, hare, rabbit, &c. The fur, properly so called, of various amphibious animals, as the seal and beaver, is protected by a coating of long coarse hair; this hair requires to be removed prior to the short fur being sheared off for the purpose of covering hats. This is generally effected by hand, for which purpose women and children are employed; but a patent has recently been obtained by Mr. A. Bell for a machine for performing the operation, the mechanical arrangements of which appear to be simple and effective. The skin passes round a projecting bed, and is advanced by machinery arranged for that purpose, the tension of the skin being duly maintained by weights. In front of the projecting bed are two cylinders of greater length than the width of the skins, and four or five inches in diameter. Over the circumference of each of these cylinders, but in contrary directions, is wound, in a spiral line, a projecting rib; each of these ribs making only one revolution of the cylinder in spirally traversing its entire length. These cylinders are driven by means of a rigger on the axis of the lower one, and are placed so near to each other as to occasion the ribs to come in contact and to press whatever hair or fur comes between them. As the skin is drawn forward over the edge of the projecting bed the long hairs stand nearly at right angles to the ribs on the cylinders, which, in their revolution, forcibly seize the hairs, and extract the same. In order that the pressure of the ribs may be somewhat elastic, and take better hold of the hairs, they are covered with leather.

FURLONG. A measure of length, equal to the eighth part of a mile, or forty poles.

FURNACE. A vessel or apparatus, wherein fuel is burnt in chemical, manufacturing, and culinary operations. Furnaces are as various, and even more so, than the particular objects for which they are designed; to accomplish these so that they shall perform their offices in the most economical and convenient manner, is the proper study of those who have to construct or employ them. The proper choice of materials, adapted to the degree of heat and other circumstances, is also of the greatest importance; indeed, the resulting products of furnaces greatly, and often wholly, depend upon the combined application of chemical knowledge, manufacturing experience, and inventive skill. The following appear to be the essential qualifications of a good furnace: first, to be able to concentrate the heat, and direct it as much as possible to the substances to be acted upon; second, to prevent the dissipation of the heat after it is produced; third, to obtain the greatest quantity of heat from a given quantity of fuel; fourth, to be able to regulate at pleasure the necessary degree of heat, and have it wholly at the operator's management. Under the articles BOILER, IRON, AIR, FOUNDRY, and various others that occur in this work, numerous practical examples are given of the construction of furnaces; it will therefore be our business, under the present head, to supply the deficiencies that are left on the subject, which we shall premise by some observations on the nature and proper construction of furnaces in general. In the construction of furnaces for boilers every thing should be combined that has a tendency to add to the effect of the fuel, and to avoid that which is calculated to diminish its effect; but without a knowledge of the nature of burning, we should be like seamen traversing the ocean without a compass. When a portion of fuel is ignited in a *close* fire-place it must be supplied with air to enable it to burn: and the fuel itself in the process of burning is partly converted into gaseous matter, which escapes up the chimney with a portion of the air supplied to the fire; but the greater part of the air so supplied ought (as Mr. Tredgold observes)

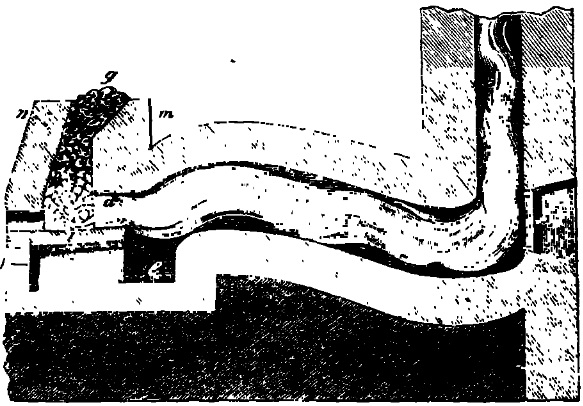
to be changed in the process, by its oxygen uniting with the carbon, and other combustible parts of the fuel, forming carbonic acid gas, vapour, &c. Now, in order that perfect combustion, or burning of the fuel, may take place, the air should have free access to every part of the fuel, which is heated sufficiently to burn; as fuel must be heated in a certain degree, otherwise its elements will not combine with the oxygen of the air. And we see clearly the advantages of a regular supply of fuel: this advantage is greater in proportion to the quantity of hydrogen contained in the same; for if a large body of such fuel be at once put upon the fire, much of the hydrogen will escape in a gaseous state unconsumed, carrying off with it a very considerable portion of heat; whereas if the fuel be thinly scattered over the surface of the fore part of the fire the hydrogen would most likely be consumed in passing over the red hot embers in the after part of the fire, and the product go off in steam; and that the latent heat of such steam may not be lost, it will be desirable to have a horizontal flue of metal for the smoke to pass along after it has left the boiler, when the steam can be condensed, and the heat applied to warm water for the boiler or other useful purposes. But to succeed in consuming the combustible gases, it is necessary that they should mix with the air that has become hot by passing (as expressed by Mr. Watt, in the specification of his patent in 1785,) "through, over, or among, fuel that has ceased to smoke," or by being drawn through small flues or channels in the brickwork round the fire, in such a manner as to be heated before it mixes with the gas to be consumed; but unless hydrogen, or some of its combinations, are constantly passing off, the introduction of a stream of air into the fire-place will only take away the heat from the boiler; and therefore in a slow fire, consisting chiefly of carbon, it will do more harm than good; while in a quick fire of cherry coal, or cannel coal, in which hydrogen is abundant, it must be a great advantage, and particularly when the fire is regularly supplied with fuel. The quality of the air to supply the fire, Mr. Tredgold remarks, is worthy of being considered, although any dirty wet hole is usually esteemed good enough for the fire place. Now the air ought to be dry, for air charged with moisture is improper, and only takes away heat; but where there is a very low chimney, and consequently an imperfect draft, some water in the ash-pit will increase the draft, by being converted into steam by the heat of the ashes, the mixture of the steam rendering the smoke much lighter than common air. The air should be cool when it enters the ash-pit, that it may pass with greater velocity through the fire, and the fire-place shed should be dry, in order that the apparatus may be durable, and be kept in order with little attention. The opening to admit air to the fire should be sufficiently large for producing the greatest quantity of steam that can be required, but not larger, and it should be constructed so as to increase in size as it approaches the fire. The area of the spaces between the bars should clearly be much greater than the area of the place that admits air to the fire. The fire should be made immediately under the boiler or other vessel to be heated, that its full effect may be exerted upon the bottom; and after quitting the fire, the mixture of flame and smoke should pass through a wide and shallow aperture, called the throat;—wide, that it may spread under the greatest surface of the boiler; and shallow, that it may pass through with considerable velocity, and consequently be impelled against the bottom of the boiler. In making the flue circulate, according to the usual mode, round the sides of a long boiler, the heat never extends far enough to render it effectual throughout its length, and the action being oblique the advantage gained is very trifling; for the same reasons, the making of a flue to return through the boiler offers no advantage that compensates for its complexity of construction, since the heat may as well be confined to act upon the bottom, and have less depth of water. The depth of fuel to be on fire at the same time should be sufficient to ignite the fresh fuel, without impairing its action on the boiler in a sensible degree. From the observations and experiments made by Mr. Tredgold to determine this point, it appears that the depth of burning fuel should be about three or four times the depth of what is added at a time in feeding the furnace; that is, four times when you feed frequently,

and three times when you feed seldom; and according to the nature of the fuel, there will be greater or less space wanted between the bars and the boilers. In the construction of furnaces, the slowest conductors of heat should be used; some metal work is absolutely necessary—that is, simply the bars and a frame at the mouth, where the fuel is put in, with or without a door; in the latter case, the space is to be filled with fuel. The rest of the brickwork should be built with hard well burnt bricks; and in order to confine the heat to the boiler, it will be proper to leave cavities in the brickwork; and, with the exception of the necessary ties, to form a double wall, with a hollow space between, keeping the maxim of Morveau always in view—to insulate the fire-place from all bodies that are rapid conductors of heat. Between the fire door and the bars there should be a dead space; on this the fresh coals are laid, previous to their being pushed forward on the grate, which should not be done until they have given out their gas over the brightly ignited fuel on the bars. This dead space is usually covered with an iron plate, called a dead plate, but it is preferable to floor it with fire tiles, as the latter are less liable to affect the fittings of the door and frame. The bars are of course proportioned to the size of the furnace; they are usually from $1\frac{1}{2}$ to 3 inches in depth, and the thickness varying from $\frac{3}{4}$ to $1\frac{1}{4}$ inch; the length seldom exceeds three feet; and where a more extended grate is required, they are generally laid in separate lengths upon transverse bearing bars, which receive both ends. The spaces between the bars are from $\frac{3}{8}$ to $\frac{1}{2}$ an inch. The whole area of the grating should be about one-fourth the area of the bottom surface of the vessel to be heated; each foot of such grating is adapted, according to Mr. Tredgold's calculations, to burn one-eighth of a bushel of coal per hour. The same area will answer for either a slow or a quick fire, but in a slow fire a greater depth of fuel is necessary; and also for equal bulks of any other kind of fuel, the same area will apply as for coals; but it will be obvious from this rule that the areas to produce equal quantities of steam will be inversely as the power of the fuel. The damper is best situated at the opening into the flue; it should be supported in its slide by a counterbalance weight, and its action be rendered easy and certain. The door should be made to shut as close as possible; but there is a difficulty in keeping it so, when exposed much to the action of the fire; they are best defended by making them double, with a hollow space for air between them. Mr. Atkinson's mode of constructing them is good; he rivets on the inside a hollow cast-iron box, which just fits the doorway; the depth of the sides of the box so strengthens the door as to prevent its warping, while the hollow space of confined air prevents the escape of heat. A sliding door, balanced by a weight, in the manner of a sash window, has many advantages; it is more easily opened and shut; is out of the way when open, and shuts close: when any thing is to be done at the fire, a smaller opening suffices.

Delasme's Furnace.—The invention of a mode of constructing furnaces calculated to burn all the smoke given out by the fuel, is usually attributed to our celebrated countryman, Mr. James Watt; but it appears from the volume of the Academy of Sciences, at Paris, for 1699, that some successful experiments were made by M. de la Hire, which had reference to an invention of many years previous date, by Delasme, a French engineer. The latter, we are told, exhibited his furnace for consuming its own smoke at the fair of St. Germain, in the year 1685. The fire-place of Delasme consisted of a long tube, bent into the form of a syphon, and inverted, the longest leg of which formed a chimney, and the shortest the furnace. The fuel was deposited on a grating near the top of the shortest leg, being supplied from above. Soon after the ignition of the fuel the heat was communicated to the longest leg or chimney, and by that means a current of air was caused to pass downward through the fuel, and under the grate, where the smoke was consumed.

Watt's Patent.—The earliest application in this country of apparatus for consuming the dense smoke of furnaces, that we are acquainted with, is the invention of Mr. Watt, in 1785, before alluded to. It is thus described by him in his specification: "My newly improved methods of constructing furnaces or fire-places, consist in causing the smoke or flame of the fresh fuel, in its way

to the flues or chimney, to pass, together with a current of fresh air, through, over, or among fuel which has already ceased to smoke, or which is converted into coke, charcoal, or cinders, and which is intensely hot; by which means the smoke and grosser parts of the flame, by coming into close contact with, or by being brought near unto, the said intensely hot fuel, and by being mixed with the current of fresh or unburned air, are consumed or converted into heat, or into pure flame, free from smoke. I put this in practice, first, by stopping up every avenue or passage to the chimney or flues, except such as are left in the interstices of the fuel, by placing the fresh fuel above or nearer to the external air than that which is already converted into coke or charcoal; and by constructing the fire-places in such manner that the flame and the air which animates the fire must pass downwards, or laterally, or horizontally, through the burning fuel, and pass from the lower part or internal end or side of the fire-place to the flues or chimney." Mr. Watt then gives an example and a description of the application of this principle in his specification, which we do not here insert, as there have been some improved arrangements introduced which we shall have occasion to notice elsewhere. The specification next proceeds to state as follows: "In some cases, after the flame has passed through the burning fuel, I cause it to pass through a very hot funnel, flue or oven, before it comes to the bottom of the boiler, or to the part of the furnace where it is proposed to melt metal, or perform any other office, by which means the smoke is more effectually consumed. In other cases, I cause the flame to pass immediately from the fire-place into the space under a boiler, or into the bed of a melting or other furnace." We annex the inventor's example of this arrangement of the furnace, as it is simpler than the former, and equally effective. *a a* represents a reverberatory furnace, for melting iron, of which *b* is the



flue; *e* is the ash-pit, and *f* a door thereto; *g* is a hopper-like receptacle for the fresh fuel, which gradually sinks down as it is consumed beneath;—about the middle of this mass of fuel it is intensely hot, as it consists of coals and coke that have ceased to smoke. At *i* is an opening or openings to admit fresh air, and regulate the fire. At the opposite end of the furnace is another door, to be used either for charging the furnace or stopping its operation, which is effected by the counter current produced by the opening of the door. The fire is first lighted upon the brick arch *l*, and when well ignited, more fuel is gradually added, until it is filled up to *g*, care being taken to leave proper interstices for the air to pass, either among the fuel, or between the fuel and the front wall; and as much air is admitted at the opening *i* as can be done, without causing the smoke to ascend perpendicularly from *g*, which it would do if too much be so admitted. "Occasionally the opening at *g* is closed with

a cover, to cause the air to enter wholly or partially at *i*." By this addition, it will be noticed, Mr. Watt first applied the closed hopper, now so much used in the feeding of furnaces.

The following figure exhibits another admirable contrivance of Mr. Watt's, which many succeeding inventors have claimed as their own, as well as that plan

already described. Mr. Watt observes,—"In some cases I place the fresh fuel on a grate, as usual, as at *a*, and beyond that grate, at or near the place where the flame passes into the flues or chimneys, I place another smaller grate *b*, on which I maintain a fire of charcoal, coke, or coals, which have been previously burned, until they have ceased to smoke, which by giving intense heat, and admitting some fresh air, consumes the smoke of the last fire."

Thompson's Patent.—Mr. Thompson had a patent in 1796 for a furnace on the same principle as Watt's, but it was a less deviation from the ordinary construction. The fire-bars were made about one third longer than usual, and at two-thirds of their length from the front a low arch was thrown across the fire-place, under which the smoke rushed from the fore part of the fire, and was thus impelled through some intensely heated coked fuel, lying under and beyond the arch upon the bars, and was thereby consumed. By the management of a good stoker, this fire-place appears to us calculated to answer well.

Roberton's Patent.—In 1801 Messrs. Roberton, of Glasgow, patented some improvements upon Mr. Watt's plans, which rendered the apparatus more complete and convenient. To these gentlemen, indeed, is usually attributed the first successful application of the principle patented by Watt, of burning the smoke owing, we are inclined to believe, to the indifference of the public in the early part of Mr. Watt's career to the nuisance of dense smoke; as, from the comparatively small number of engines at that time, the adoption of means to burn the smoke was not so much sought after. Joined to this circumstance may be reckoned the unskilful manner in which bricklayers, pretending to an adequate knowledge of the subject, executed the work; which caused the principle to get into disrepute, rather than the bungling attempts to carry it into effect. It was, in consequence, given in evidence, by numerous witnesses before a committee of the House of Commons, that *more coals were consumed by burning the smoke than allowing it to pass off unconsumed!* in other words, that inflamed gas afforded less heat than cold smoke. The probability is, that more air was admitted than was requisite to supply the necessary quantity of oxygen to the carbonaceous matter, and that in consequence of such

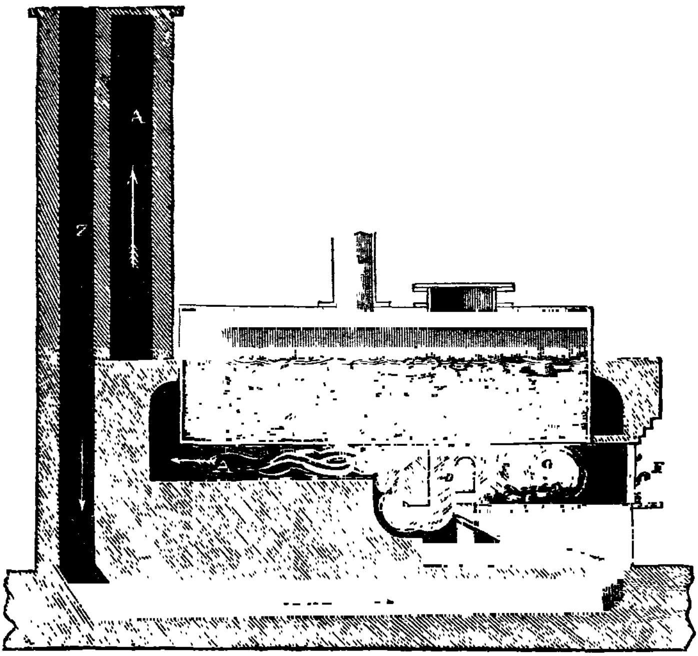
management, the temperature of the furnace or of the boiler was reduced, requiring an additional quantity of fuel to get up the requisite heat.

Sheffield's Patent.—In the year 1812, Mr. William Evetts, of Sheffield, took out a patent for improved reverberatory furnaces for melting metals, in which he introduced what he termed an *air conductor*, for the purpose of conveying a stream of pure air upon the surfaces of the metallic substances under reduction. This air conductor consisted of a vertical passage or tube, made in the bridge or wall of brickwork at the back of the furnace, the lower end of which opened into the ash pit, where it was widened, and the size of the aperture regulated by a valve, which valve was operated upon by a long rod passing through the front enclosure of the ash pit; the upper extremity of the air tube or passage did not pass vertically *through* the bridge, but had a horizontal turn given to it, by which the jet was thrown upon the substances under operation, or against the current of heated vapours, before they passed over the bridge; and this minor stream of fresh air was found to impart sufficient oxygen to the carbonaceous matter of the smoke, and burn it.

Legislative Enactment.—The annoyance and pernicious effects experienced by the public from a sooty atmosphere, drew the attention of the legislature to the subject, and a Select Committee of the House of Commons was appointed, in 1819, "to inquire how far it might be practicable to compel persons using steam engines and furnaces in their different works, to erect them in a manner less prejudicial to public health and comfort; and to report their observations thereon to the House." The committee having ascertained and reported to the House that the reduction of smoke from furnaces might be practically accomplished, a bill to embrace that object was brought into the House and passed; it was entitled—"An Act for giving greater facility in the prosecution and abatement of nuisances arising from furnaces used in the working of steam-engines:" to commence Sept. 1, 1821. Among its enactions are the following;—"That it shall and may be lawful for the court before whom any such indictment shall be tried, in addition to the judgment pronounced by the said court, in case of conviction, to award such costs as may be deemed proper and reasonable to the prosecutor or prosecutors, to be paid by the party or parties so convicted." It was also enacted—"That if it shall appear to the court before which any such indictment shall be tried, that the grievance may be remedied by altering the construction of the furnace, or any other part of the premises of the party or parties so indicted, it shall be lawful to the court, without the consent of the prosecutor, to make such order touching the premises as shall be, by the said court, thought expedient for preventing the nuisance in future, before passing final sentence upon the defendant, or defendants, so convicted."

Gregson's Patent.—Mr. Joseph Gregson, who was one of the gentlemen examined before the Committee of the House, gave it as his opinion, that the principal causes of the nuisance were, the putting on the fire too much crude fuel at a time, and the chimney being in general too low. Mr. Gregson had a patent for a plan of a furnace for consuming the smoke, the principle of which, he stated, consisted, "first, in causing all the smoke, after it has arisen from the fire, to return into the heat of the fire before it enters the flue or chimney, and so be consumed; secondly, in putting on no more fuel at any one time, than the smoke of which can be consumed, and that without opening the door for the purpose; thirdly, in supplying the fire with a current of air to counteract the effect of those winds that operate against the draft. The engraving in the next page represents a vertical section of the apparatus. The fire-place G and the feeding-door F are made as usual; the smoke passes over the bridge D, under which is an aperture, where an intense heat is produced, which inflames the smoke in the descending flue by means of a supply of air through the aperture C; it then passes into the flue and the chimney, A, formed in the usual manner. Z Z is an air shaft and drain to supply the fire with air through a valve situated under the fire-place. It may be deserving of remark, that the objects aimed at by Mr. Gregson in this arrangement would be considerably promoted, by making the partition between the ascending and descending flues, A and Z, of iron or copper, instead of brick; and that an economy of fuel

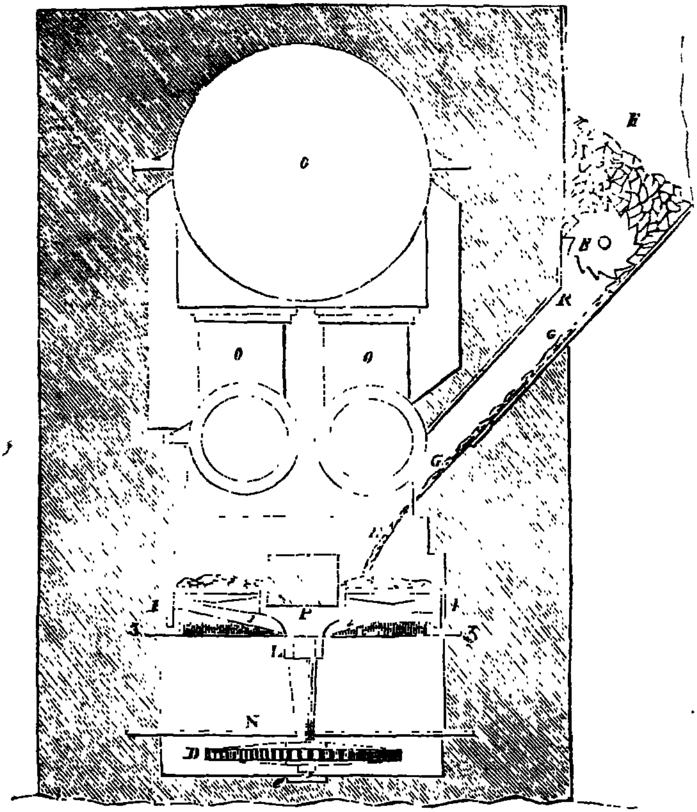
would result from the partial exchange of temperatures between the opposite currents. But in thus abstracting the waste heat through the medium of good conducting substances, a sufficient temperature must be left in the ascending column to maintain the draft.



Losh's Patent.—The entire specification of this gentleman's improvements is inserted in the *Repertory of Arts*, and is deserving of perusal by those who are interested in the subject; the leading arrangements may however be understood by the following extract. The plan arranges "the furnace bars as near as possible under the middle of the boiler, or other vessel's bottom, and to have the aperture or apertures for the escape of the rarefied air and smoke above the door through which the fuel is put in, so that the heated air and gases, by their expansive force and diminished specific gravity, shall prevent the cold air of the atmosphere from penetrating beneath the bottom of the boiler, in order that the cold air admitted at the door where the fuel is introduced, shall, in its passage to the chimney, have no tendency to mix with the heated gases until after they have ceased to act upon such parts of the boiler as are required to be submitted to their action alone. A division of cast plates, extending from the ends of the bars next to the door, separates the grate-room from the ash-hole and air-duct, and prevents any air from passing into the grate-room which does not pass through the ignited fuel." Another peculiarity in Mr. Losh's arrangements, consists in the employment of two fires, which we will call A and B, with a wall between them, which supports the middle of the boiler across its width. Each of these fires has a common flue, which terminates in the chimney, and they communicate with each other by means of an open arch under the partition wall; each fire is supplied alternately with fuel; and the arrangement of the dampers is such, that the gas from the fresh fuel in A shall be compelled to descend, pass under the arch of the division wall, and through the grate bars of the fire B, along with the fresh air that supplies it where the smoke is consumed; the current of heated air from both, thus

united, takes its course around the flue into the chimney. By the time that the fuel in A has burned bright, that in B requires replenishing; the dampers are then reversed, which removes the current to the chimney; then the gas from the fresh fuel in B descends under the beforementioned arch up through the grate bars of A, along with the fresh air of supply, and being there ignited, is conducted to the chimney. In this alternate manner the operation of feeding is continually repeated.

Steel's Improvement.—Mr. Steel's fire-place was of a circular form, and made to revolve on an upright axis by a gear connected to its lowest extremity; motion was also given, at the same time, to a fluted roller, turning in bearings underneath a hopper filled with coals; this roller broke or crushed the coals to a sufficiently small size, and projected them down an inclined shoot, which distributed them over the circular grate as it turned round, as represented in the annexed section. *o o o* shows a high pressure tubular boiler, set in masonry;



i i is the ring or rim which surrounds the circular grate, made somewhat deeper than the bars, and turning round in an iron trough 3 3, filled with sand, which prevents the air from passing by the rim; N is a metallic plate to receive the ashes which fall; D a toothed wheel, turned by any convenient means in the step at C, and in a cross bar at L above. At F is the receptacle for the fuel; E the breaking and supplying roller, which projects them down the inclined shoot G R, into the revolving grate, which, continually presenting fresh surfaces,

the fuel is pretty uniformly distributed thereon. The grate is made to turn in such a direction that the fresh coals are, immediately after they are deposited, presented to the fire door contiguously situated, where, by the due admission of air, vivid combustion immediately takes place, and the fresh fuel is in bright ignition before more is thrown on the same part, the revolution of the grate being low.

Brunton's Patents.—Mr. Brunton had a patent in 1819 for a revolving fire-grate of a similar kind; but whether Mr. Steel's was antecedent to it (as would appear from the dates given, together with the circumstances), we do not know. Mr. Brunton has, however, the credit of carrying his apparatus into successful use, and of having rendered it very complete. Among many judicious contrivances, may be noticed a revolving scraper, which gathered up the ashes as they fell upon the ash plate. In the following year, 1820, Mr. Brunton took out a second patent for improvements upon the former; these chiefly consisted in a mode of raising or lowering the furnace at pleasure, so as to diminish or increase the heat of the boiler as required; also in a new mode of feeding the fire. The shaft of the circular fire-grate upon which it revolves, is made to pass through a hole in a bearer of iron, built in the brickwork, and receives its support at bottom upon another bearer of iron, which is capable of sliding up and down in grooves, so as to elevate or depress the fire, by means of a rack and pinion, acted upon by a lever or winch. Round the periphery of the circular grate is a double rim of sheet-iron, rising up three or four inches, the space between being filled with sand, so that when the grate is raised, another ring of iron, attached to the wall of the furnace, may fit into the groove and form a sand valve, to prevent the passage of air, and check the transmission of heat. Two or more passages, provided with sliding doors, are made through the brickwork, for the purpose of admitting a current of air to the top of the fire, in order to assist in igniting the smoke, if necessary. The fire feeder is shaped like a hopper, placed over the feeding hole, and the delivery aperture at bottom is capable of contraction or expansion, as may be required. Below this is a plate of iron, placed in an inclined position, and suspended upon pivots for the purpose of being agitated, in order to distribute the fuel equally upon the grate; there is also a shovel upon rollers, moved by means of a rod and chain actuated by the engine. By the very equal distribution of the coal upon the grate, a thin fire and a sharp draft is maintained, owing to every piece of coal upon the grate being successively exposed to a current of the fire passing constantly in one direction across the grate; the continual dropping of the coal in minute quantities, instead of opening the door to charge as usual, produces a great advantage in convenience, besides a saving of fuel. The introduction of the coal is likewise completely governed by the steam generated, so as to admit no more for combustion than is actually needed for the due performance of the work of the engine. The whole apparatus acted independently of the skill or of the carelessness of the fireman. Small coal, of greatly inferior cost to that generally used, answers well with a furnace of this kind, and thereby effects an important saving. A thin fire with a sharp draft produces the maximum effect, because the greater the quantity of oxygen brought into contact with the coal in combustion, the greater heat is obtained.

Murray's Improvement.—It has doubtless been observed by most of our readers, that the very dense black smoke which issues from the chimneys of steam engines and other furnaces, is not constant; that it commences at the time of putting on fresh fuel, and continues for a few minutes afterwards. At this time the air finds its way through the fuel with less opposition, and the evolution of dense smoke ceases until the next charge of coals. To supply the requisite quantity of air to burn this black smoke, the late Mr. Murray (the celebrated steam-engine manufacturer of Leeds), devised a very ingenious machine. It is described in a letter addressed to the Editor of the *London Journal of Arts*, dated February 15, 1821, wherein he observes,—"The most effectual method yet known for consuming smoke, is by the admission of a large quantity of air to the hottest part of the fire, at the time the smoke is bursting

from the recent charging of coal. The necessary quantity of air to be admitted ought not to be less than may pass through an aperture of *four square inches for each horse power* that the boiler or fire is equal to; this will consume the smoke in from three to five minutes, according to the quantity and quality of coal put on at each time,—the times of charging being not more than five times in an hour, nor less than three. The air rushing into the flue is the moving force for giving motion to my new regulating machine, which continues in motion during the consumption of smoke, but no longer." The machine may be thus described, without the drawings given in the work before alluded to. It consists of a light fan-wheel, from which proceeds a capacious tube, communicating with the fire-place, and containing a turning valve, which opens or closes the passage. When the fire-door is opened to take in fresh fuel, it discharges (by means of a slip catch connected to the door) a pall, which sets at liberty a suspended weight; the descent of this, turns a ratchet wheel, which places the turn-valve edgeways against the current, and leaves a free communication between the atmosphere and the upper side of the fire. In this state of rest the machine remains until the fire-door is shut, when the current of air enters the machine, turning rapidly the fan-wheel, which having a pinion on its axis of only one tooth, gives a slight motion to a light spur-wheel of many teeth; this wheel, through the medium of a catch-rod, and other simple mechanism, gradually closes the turn-valve. The smoke having been consumed, the fire continues burning until a fresh supply of fuel is necessary, when the fire-door is opened, which puts the machine in a state for measuring off the required quantity of air to be admitted to consume the smoke of each charge; the operation is then repeated.

Pritchard's Patent.—Mr. William Pritchard took out a patent in 1821 for the same object. He fixed a small cylinder in some convenient place contiguous to the furnace, with an air-tight piston to rise and fall within it. At the upper end of the piston-rod a chain is attached, which passes over pulleys, and its reverse end is connected to the top of the fire door or air-flue doors, by means of which connexion, when the fire door is raised, the piston descends in the cylinder by its own gravity; and when the fire door is shut down, the piston rises. On the outside of the cylinder is placed a branch pipe or channel, through which the air passes (as the piston ascends or descends) from the upper to the lower part of the cylinder, and *vice versâ*. In the middle of this branch pipe is a valve or stop-cock, which may be so adjusted as to suffer the air to pass slowly, or by a very small stream, through the channel; by this means the ascent of the piston is retarded, and hence the entire descent, or closing of the fire doors, or air-flues, does not take place, until the air is nearly all expelled from the upper part of the cylinder, allowing time for the requisite quantity of atmospheric air to pass into the air-flues over the fire, for the purpose of consuming the smoke; the time of closing the doors is regulated, as above, by the valve or stop-cock in the branch pipe.—*London Journal of Arts.*

Stanley's Patent.—This invention, which we have seen repeatedly and successfully applied, forms a distinct appendage to the front of the furnace. At the upper part of the apparatus is a hopper, containing a supply of *small* coals adequate to an hour or two's consumption. Through an aperture at the lower extremity of this vessel, the coals drop between two grooved rollers, which revolve in opposite directions, and break those which are too large to pass without reduction between them; they then fall upon a flat plate of iron, whence they are continually projected by the arms of a kind of revolving fanner, which scatters them evenly over the burning fuel on the grate, where it lies in a thin bed, in order that the air may pass upward through them the more easily. The apparatus is, however, usually adjusted to throw a larger proportion of the fuel near the fire bridge, so that it may lie there heaped up or in a thicker stratum, in order that the small quantity of smoke arising from the fresh fuel in front may be consumed in passing over the bridge.

Chapman's Furnace.—In 1824 Mr. Chapman received a reward from the Society of Arts for a different mode of introducing air into the furnace. He casts the grate bars hollow from end to end, so that they form a series of

parallel tubes, which open into two boxes, one placed in front, and the other behind the grate. In the front box, directly underneath the fire door, there is a register to open and shut to any extent, at pleasure; the other end is connected with the brickwork, directly under the fire bridge, which fire bridge is made double, with a small interval between, about one inch, the interval to go across the furnace from side to side, and rather to incline forward, or towards the fire door, so as to meet and reverberate the smoke on to the ignited fuel in the grate, which causes it to inflame and become a sheet of bright fire under the bottom of the boiler. By this arrangement it will be perceived, that if the front register is open, or partially so, there will be a great draft of air through it, along the interior of the grate bars, thence into the flue of the fire bridge, and out of the orifice at top, which air will be heated in its passage through the bars before it comes in contact with the smoke, when it will give out its oxygen, and cause it to inflame. Mr. Chapman's mode of supplying the coals to the furnace is also simple and excellent, which will be explained with reference to the subjoined engraving. *Fig.* 1 is a section of the furnace, with a boiler

Fig. 1.

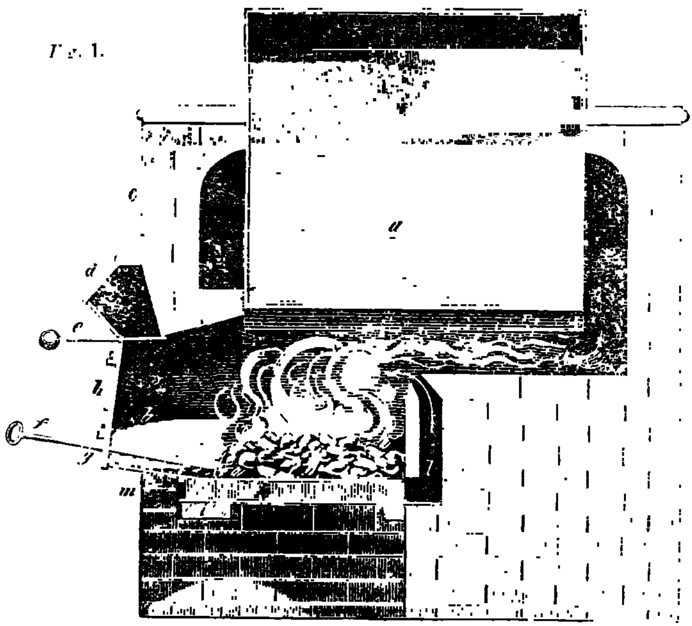


Fig. 2

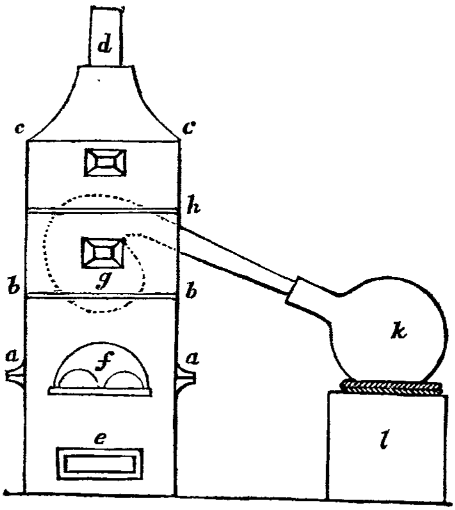
fixed therein; and *Fig.* 2 a view of the hollow bars as they open into the box *i*. *a* is the boiler; *b* the fire-place; *c* the feeding hopper, with a cover *d*, and its type or turning bottom, having a lever or counterpoise *e*, by means of which the coals are delivered into the fire-place; *f* is a rake, by means of which the half-burnt coals are pushed forward previously to letting in a fresh charge; *g* a slit below the furnace door, through which the state of the fire is seen; *i i* is an air-tight box, into the back of which the bars open, and in front of which is a register for the admission of air; *k* one of the hollow bars, the whole of which are shown in *Fig.* 2 as they open into the box *i* above mentioned; *l* a flue in the fire bridge, through which the air having passed into the box *i*, and thence

through the hollow bars *k*, enters into the furnace, and consumes the smoke. Hollow bars are said to be more durable than solid.

Gilbertson's Patent.—This differs but little from the former. Mr. Gilbertson's plan is to heat the air by causing it to pass through "hollow plates" fixed to the sides of the furnace, and thence into a cavity at the back of the fire, where it comes in contact with the smoke, and causes it to be ignited.

Chemical Furnaces.—The forms of furnaces employed by experimental as well as practical chemists are extremely diversified. Those which are employed in manufactories; in metallurgical, distillatory, and other operations on the great scale, will be found under the denomination of the article produced, such as IRON, GAS, ZINC, &c. In this place, therefore, we shall confine our notice to those portable furnaces which are generally employed by British chemists.

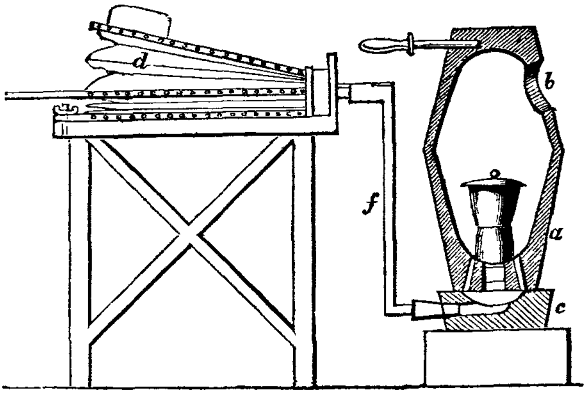
Reverberatory Furnace.—Annexed is the common reverberatory furnace. At *a a* is the ash pit and fire-place; *b b* the body of the furnace; *c c* the dome or



reverberating roof; *d* the chimney; *e* door of the ash pit; *f* door of the fire-place; *g* handles of the body; *h* aperture to receive the head of the retort; *i* handles of the dome; *k* receiver; *l* stand of the receiver; *m* retort, represented in the body in dotted lines.

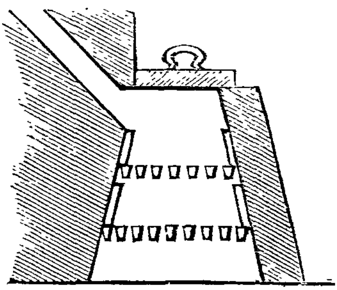
Aikin's Portable Blast Furnace is represented in the figure on the following page; it is composed of three parts, all made out of the common thin black lead melting pots, sold in London for the use of the goldsmith. The lower piece *c*, *Fig.* 1, is the bottom of one of these pots, cut off so low as only to leave a cavity of about an inch deep, and ground smooth above and below. The outside diameter, over the top, is five inches and a half. The middle-piece, or fire-place *a*, is a larger portion of a similar pot, with a cavity about six inches deep, and measuring seven inches and a half over the top outside diameter, and perforated with six blast holes at the bottom. These two pots are all that are essentially necessary to the furnace for most operations; but when it is wished to heap up fuel above the top of a crucible contained, and especially to protect the eyes from the intolerable glare of the fire when in full height, an upper pot *b* is added, of the same dimensions as the middle one, and with a large opening in the side, cut to allow the exit of the smoke and flame. It has also an iron stem with a wooden handle (an old chisel answers the purpose very well,) for removing it occasionally. The bellows, which are double (*d*), are firmly fixed by a little contrivance, which will take off and on, to

a heavy stool, as represented; the nozle is received into a hole in the pot *c*, which conducts the blast into its cavity. No luting is necessary in using this furnace, so that it may be set up and taken down immediately. Coke, or



common cinders, answer well for fuel; and the heat which this little furnace affords is so intense, that its power was first discovered by the fusion of a thick piece of cast-iron.

Chevenix's Wind Furnace is represented in the following engraving. It is, in some respects, Dr. Ure observes, to be preferred to the usual form. The sides, instead of being perpendicular, are inclined, so that the hollow space is pyramidical. At the bottom the opening is thirteen inches square, and at the top eight. The perpendicular height is seventeen inches; the form appears to unite the following advantages: 1st, A great surface is exposed to the air, which, having an easy entrance, rushes through the fuel with great rapidity; 2d, The inclined sides act in some measure as reverberating surfaces; and 3d, The fuel falls of itself, and is always in close contact with the crucible placed near the grate. The late Dr. Kennedy, of Edinburgh, whose opinion on this subject claims the greatest weight, found that the strongest heat in our common wind furnaces was within two or three inches of the grate: this, therefore, is the most advantageous position for the crucible, and still more so when we can keep it surrounded with fuel. It is inconvenient and dangerous for the crucible to stir the fire often to make the fuel fall; and the pyramidal form renders this unnecessary. It is also more easy to avoid a sudden bend in the chimney, by the upper part of the furnace advancing in this construction.



Lamp Furnaces.—The flame of an argand lamp is very often employed for chemical purposes, and it is very convenient. To a vertical rod is fitted to slide thereon a number of metallic rings projecting from it horizontally, which become the supports to retorts, or other vessels suspended over the flame of the lamp.

Domestic Furnaces, such as stoves, grates, ranges, &c. are described under the article Fire-place.

FUSEE, in Clockwork, the conical barrel drawn by the spring, and about which the chain or cord is wound; for the use of which see Horology.

FUSION, in Chemistry, the application of heat to produce the dense fluid state of bodies.

FUSTIAN, in Commerce, a kind of cotton stuff, which seems as if it were whaled on one side. Right fustians should be made entirely of cotton; but they are frequently made with a warp of flax.

FUSTIC, OR YELLOW WOOD. This wood, the *Moras tinctoria*, is a native of the West Indies, and affords much colouring matter, which is very permanent. The yellow given by fustic without any mordant is dull and brownish, but stands well. The mordants employed with weld act upon fustic in a similar manner, and by their means the colours are rendered more bright and fixed. The difference between them is, that the yellow of fustic inclines more to orange than that of weld; and as it abounds more in colouring matter, a less quantity will suffice.

G.

GALBANUM. A resinous and gummy juice that exudes from the *Bubon galbanum*. The commercial article is in the state of white, yellow, and brownish tears, unctuous to the touch, and softening between the fingers, and generally full of bits of stalks, leaves, &c. of the plant; it has a bitter acrid taste, and strong smell. One pound of galbanum yields to alcohol nine and a half ounces of resin, and to water about three ounces of gum. The peculiar smell and taste of galbanum reside in an essential oil, six drachms of which are obtained by distillation from one pound of the substance.

GALENA. The native sulphate of lead.

GALLEY, in Printing, a frame into which the compositor empties the lines of type out of his composing stick, and in which he arranges and ties up the whole matter of the page when it is completed. The galley is an oblong square board, with a ledge on one of its sides and one of its ends, to support the type in drawing it up into a compact mass; it has sometimes a groove to admit a false bottom, called a galley-slice.

GALLEY. A kind of low, flat-built vessel, furnished with a deck, and navigated with sails and oars; chiefly used in the Mediterranean. This term is also given to a light species of open boats employed in the river Thames, which is rowed with six or eight pair of oars.

GALLIC ACID is found most abundantly in the vegetable substance galls, whence it derives its name; but most astringent vegetable matter contains it. The simplest mode of obtaining it is probably that recommended by Mr. Fiedler. An ounce of powdered galls is to be boiled in sixteen ounces of water until reduced to eight, and then strained. Dissolve two ounces of alum in water, precipitate the alumina by carbonate of potash; and after edulcorating it completely by repeated ablutions, add to it the decoction, frequently stirring the mixture with a glass rod; the next day filter the mixture; wash the precipitate with warm water till this will no longer blacken sulphate of iron; mix the washings with the filtered liquor, evaporate, and the gallic acid will be obtained in fine needle crystals. The gallic acid, placed on a red-hot iron, burns with flame, and emits an aromatic smell like that of benzoic acid. It is soluble in twenty parts of cold water, and in three parts at a boiling heat. It is more soluble in alcohol, which takes up an equal weight if heated, and one-fourth of its weight cold. The distinguishing characteristic of gallic acid is its great affinity for metallic oxides, so as, when combined with tannin, to take them from the powerful acids. The more readily the metallic oxides part with their oxygen, the more they are alterable by the gallic acid. To a solution of gold it imparts a green hue; mercury it precipitates of an orange yellow; copper, brown; bismuth, a pale yellow; lead, white; and in iron, a black; whence its use in making ink, and in the operations of the dyer in making various shades of black, and in improving or fixing other colours.

GALLON. An English measure of capacity, which, until recently, varied considerably with the kind of goods measured by it; thus—

The gallon wine measure	contained	231	cubical inches.
Ditto beer measure,	„	282	„
Ditto dry measure,	„	$268\frac{4}{5}$	„

But by an Act of Parliament passed in 1824, it was altered on the 1st of May, 1825, to an uniform measure called the imperial standard gallon. By that act it was determined to be such measure as shall contain ten pounds avoirdupois of distilled water, weighed in air at the temperature of 62° Fahr., and the barometer at 30 inches; and such measure is declared to be the "Imperial Standard Gallon," and shall be the unit and *only* standard measure of capacity to be used, as well for wine, beer, ale, spirits, and all sorts of liquids, as for dry goods not measured by heap measure; and that all other measures shall be taken in parts or multiples of the said imperial standard gallon, *the quart* being the fourth part of such gallon, and *the pint* one-eighth part; two such gallons making *a peck*, eight such gallons *a bushel*, and eight such bushels *a quarter* of corn, or other dry goods not measured by heaped measure.

GALLS. The protuberances on various kinds of trees, supposed to originate in the puncture of an insect. Some are hard, and are therefore called nut-galls; others soft, which are called berry, or apple-galls. The best are the nut-galls of the oak; and the most esteemed of this species are brought from Aleppo. They are not smooth on the surface, but tubercular, small and heavy, and should have a bluish or blackish tinge. By infusing 500 grains of Aleppo grains broken into small pieces in distilled water, Sir H. Davy obtained, by evaporating the fluid, 185 grains of solid matter, which, on analysis, gave 130 of tannin; 12 mucilage and insoluble matter; gallic acid, with a little extractive matter, 31; remainder calcareous earth and saline matter, 12. The extensive use of galls in dying, tanning, and in making ink, is well known, for which see the separate articles under their initial letters.

GALL-STONES. The calculous concretions occasionally found in the gall-bladders of animals. Those found in oxen, used by painters, are of this nature.

GALVANISM. A species of electricity excited, not by friction, but by establishing a communication between two different metals through the medium of a liquid. See CHEMISTRY.

GAMBOGE. A substance obtained from the *Stalagmites cambogioides*, a tree that grows wild in the East Indies, from which it is had by wounding the shoots. It is brought here in large cakes, which are yellow, opaque, and brittle. With water it forms a yellow, turbid liquid, used in painting. In alcohol it is completely dissolved. If taken internally, it operates violently as a cathartic.

GARLIC. The root of the *Allium*. This root has been found, by chemical analysis, to consist of albumen, mucilage, fibrous matter, and water.

GARNET, in Mineralogy, a species of the flint genus, of which there are two sub-species, viz. the precious and common. The precious, or oriental, is red, but of various shades; it occurs most commonly crystallized, either as a dodecadron, or as a double eight-sided pyramid. Garnets are found in almost every country where primitive rocks exist. Switzerland and Bohemia are the two countries which furnish them in the most abundance.

GAS. The name given to all elastic æriform fluids (except the atmospheric air) which retain that state at all ordinary temperatures and pressures. For a long time the gases were supposed to be permanently elastic; but about the year 1823 Sir Humphrey Davy, assisted by Mr. Faraday, succeeded in reducing several of them to a liquid state by subjecting them to great pressure, and an extreme degree of cold; upon removing the pressure, and restoring the natural temperature, the liquids became again converted into gases. This discovery induced these gentlemen to institute a series of experiments with the view of ascertaining whether the vapours arising from the gases thus liquefied might not be rendered available as mechanical agents in lieu of steam, and be applicable to the same purposes. These experiments were detailed in a paper read at the Royal Institution, and from this paper we select the following results:—

Sulphuretted Hydrogen, which condenses readily at 3° Fahr. under a pressure

equal to the elastic force of an atmosphere compressed to one-fourteenth, had its elastic force increased to that of an atmosphere compressed to one-seventeenth by an addition of 47° of temperature. Liquid muriatic acid at 3° Fahr. exerted an elastic force of 20 atmospheres; by an increase of 22° of temperature, its force was increased to 25 atmospheres; and by a farther addition of 26°, its force became equal to 40 atmospheres. Carbonic acid at 12° Fahr. exerted a force of 20 atmospheres; and at 32° Fahr. its pressure was equal to 36 atmospheres, making an increase of pressure equal to 13 atmospheres by an increase of 20° of temperature; and this immense force of 36 atmospheres being exerted at the freezing point of water. From the above experiments, it will be seen that great accessions of force are obtained by very slight additions of heat; and Sir Humphrey observes, in the Memoir, that—"if future experiments should realize the views here developed, the mere difference of temperature betwixt sunshine and shade, and air and water, will be sufficient to produce results that have hitherto been obtained only by a great expenditure of fuel." Upon this subject Mr. Tredgold, in his excellent *Treatise on the Steam Engine*, observes,—"I think it will be found that two other circumstances should be considered in estimating the fitness of compressed gases as mechanical agents. First, the distance through which the force will act; for if this distance of its action be less in the same proportion as its force is increased by compression, no advantage will be gained; the power of a mechanical agent being jointly as its force, and the space through which that force acts. Secondly, the quantity of heat required to produce the change of temperature, is also to be considered; for if the mechanical power requires as great an expenditure of heat as common steam, no advantage will be gained; in fact, the only prospect they afford of being useful, is through lessening the extent of the surface to be heated." Mr. Tredgold then gives the following Table of the gases liquefied by Mr. Faraday, with their densities as far as can be ascertained, and with a column to show their mechanical power as compared with steam, according to the spaces through which they act, from which it will be seen that in effect they are all inferior to the latter. The quantity of fuel requisite for their vaporization is not known.

	Spec. Grav. Air—1.	Spec. Grav. of Liquid, Water—1.	Temperature.	Pressure in Atmosphere	
Carbonic acid gas . .	1.527		32°	36	
Sulphuric acid gas . .	2.777	1.43	45	2	426
Sulphur. hydrogen gas .	1.192	.9	50	17	530
Euchlorine gas . . .	2.365				
Nitrous oxide	1.527		45	50	
Cyanogen	1.818	.9	45	3.6	395
Ammonia	.596	.76	50	6.5	1057
Muriatic acid gas . . .	1.285		50	40	
Chlorine	2.496	1.33	50	4	440
Steam of water . . .	.48	1.000	212	1.	1711

GAS LIGHTING. The art of procuring and applying to the purpose of illumination the inflammable gases evolved by animal and vegetable matter when exposed in close vessels to a high temperature. This important and highly beneficial invention originated in the researches of modern chemists; but a long period elapsed between the scientific discovery of the facts upon which the process is founded, and their successful application to practical purposes. The fact that a permanently elastic and inflammable æriform fluid is evolved from pit coal during its destructive distillation, appears to have been first ascertained experimentally by the Rev. Dr. Clayton, whose account of his discovery was published in the *Transactions of the Royal Society*, Vol. XLI., for the year 1739. Dr. Hales subsequently made experiments on pit coal, and found that, when distilled in close vessels, nearly one-third of the weight of coal

passed off in inflammable vapour. Further experiments were made by Dr Watson, Bishop of Llandaff, in 1767; but no practical application appears to have been made of these discoveries for a long period. The merit of such application appears to belong to Mr. Murdock, who, in 1792, commenced a series of experiments at Redruth, in Cornwall, upon the quantity and quality of the gases contained in different substances, as coal, peat, and wood; in the course of which experiments it occurred to him, that, by confining and conducting the gas in tubes, it might be employed as an economical substitute for lamps and candles. The distillation was performed in iron retorts, and the gas conducted through tinned iron and copper tubes to the distance of seventy feet. At this termination, as well as at the intermediate points, the gas was set fire to as it issued through apertures of different diameters and forms, purposely varied to ascertain which would answer best; amongst these forms were the argand burner and the cockspur burner, which are the two most generally employed at the present day. Bags of leather and of varnished silk, and vessels of tinned iron, were also filled with the gas, which was set fire to and carried from room to room, in order to ascertain its applicability as a movable light. Mr. Murdock's constant occupations prevented his pursuing the subject further until 1797, when he renewed his experiments upon coal and peat, at Old Cumnock, in Ayrshire. In 1798 he constructed an apparatus for lighting the works of Messrs. Bolton and Watt, at Soho; and in 1802, on the occasion of the rejoicings for the peace, the whole of the works were illuminated with gas. In 1803 and 1804 Mr. Winsor made public exhibitions of the general nature of gas lighting at the Lyceum Theatre, and proposed to light the public streets by means of gas; but the extravagance of his statements respecting the advantages of the scheme were prejudicial to the plan; and although an experiment was made by lighting up a portion of Pall Mall, it was soon abandoned, and the practice did not come into successful operation until the year 1813, when the Chartered Gas Company erected their works at Peter-street, Westminster. Since this period the practice of gas lighting has come into general use with astonishing rapidity; important improvements have been made in the various processes connected with it, and gas is now extensively procured from numerous substances beside pit coal, such as oil, tar, resin, &c. We shall now proceed to give a general view of the subject, by describing the process of gas making as usually conducted at the Coal Gas Works.

A number of cast-iron vessels, called retorts, generally of a cylindrical or of an oval shape, and set in a brick furnace, are heated to redness, and then about half filled with coal, and the mouths of the retorts closed and carefully luted. In a short time the decomposition of the coal commences, and the volatile parts separating from the fixed parts, are conducted by bent tubes called dip pipes, into a large horizontal cast-iron tube called the hydraulic main, from its being half full of water, into which the ends of the dip pipes are immersed, so that the gas and vapours may be forced to pass through the water, which condenses a portion of the tar and ammonia, whilst the gas ascends to the upper part of the hydraulic main; from this it passes by a pipe to the condenser, which consists of a number of metallic pipes or compartments, surrounded by cold water. In its passage through this vessel the gas becomes so much cooled as to occasion the remaining portion of the tar and ammonia to be condensed, which latter products pass into the tar cistern, whilst the gas passes into the purifier, where it undergoes a process by which the carburetted hydrogen, which is the gas employed for illumination, is freed from the sulphuretted hydrogen, and carbonic acid evolved with it; it then passes through the gas meter, in order that the quantity may be registered on its way to the gas holder (or gasometer, as it is improperly called), in which it is stirred up till wanted for use, being conveyed in any required direction by pipes connected with the gasometer. For the further elucidation of the subject, a general view of the apparatus, with explanatory remarks, will be found on the following page. *a Fig* 1. in the following engraving, represents a portion of a bench of retorts, in which five elliptical retorts *b b* are exhibited, set in an oven, the mouth of which is covered by the cast-iron plate *c*, having apertures for the introduction of the

retorts, which are secured to the oven plate by flanges at their mouths, and the other extremity is supported by a cast-iron stud projecting from it and resting

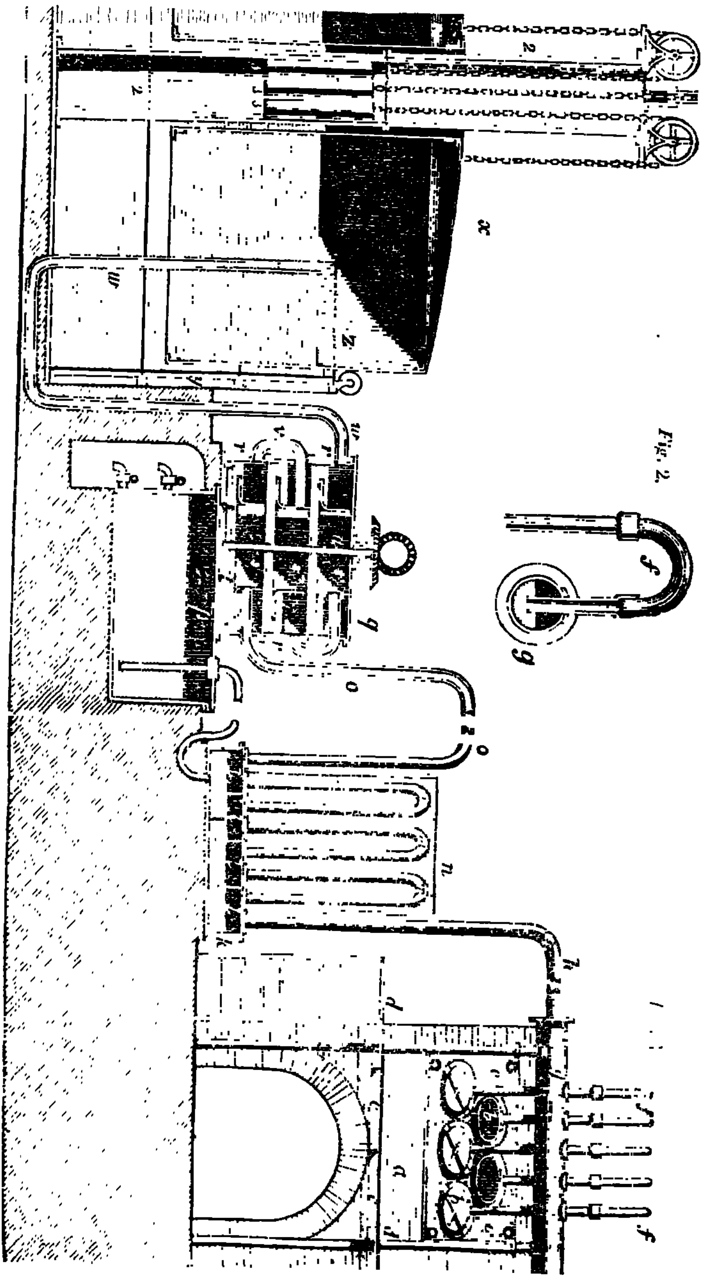


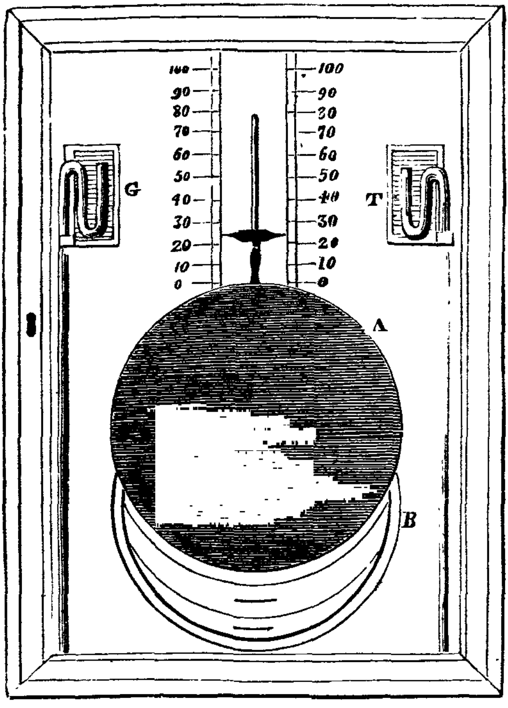
Fig. 2.

in a cast-iron socket at the back of the oven. This plan of setting retorts,

which affords great facilities in their removal when burnt out, and in replacing them with others, was first employed at the Westminster Gas Works, and is the invention of Mr. Malam, of that establishment. The fires for heating the retorts are not seen, being situated at the back of the oven, by which arrangement the annoyance of the heat to the men who charge the retorts from the elevated platform *d*, is considerably diminished; the coke, as it is raked from the retorts, falls through apertures *e e* in the platform, to which apertures are fitted trap doors, or movable gratings; *f f* are the dip pipes, by which the gas enters the hydraulic main *g*, a transverse section of which, upon a larger scale, is shown in *Fig.* 2; *h* is the pipe by which the gas is conveyed from the hydraulic main to the condenser, to be divested of the tar and ammoniacal liquor. Various arrangements have been employed for this purpose; that shown in the engraving, and which we believe to be generally preferred, is the invention of Mr. Perks, and consists of a close vessel *k* divided into compartments *l l*, each communicating with the adjacent one by parallel rows of bent pipes *m m*, which are surrounded by water contained in the tank *n*, erected upon the top of *k*. The gas entering the condenser by the pipe *h* passes successively through the several rows of bent pipes until it arrives at the exit pipe *o*, which conveys it to the purifier; by which prolonged contact with a great extent of cooling surface, the tar and ammoniacal liquor become condensed, and fall to the bottom of the compartments *l l*, and from them are conveyed to the tar vessel *p*, in which the tar, from its greater specific gravity, occupies the lower portion, and is drawn off by the lower cock, whilst the ammonia, which lies above it, is drawn off by the upper cock; *q* represents the most approved construction for a purifier when cream of lime is the material by which the carburetted hydrogen is freed from the sulphuretted hydrogen and carbonic acid, with which it is still contaminated after leaving the condenser. In this arrangement of the purifying vessels, three cylindrical vessels *r r r* are placed one over another, and from the top of each descends a smaller cylinder *s s s*, which does not reach the bottom of the larger cylinder, and which has attached to its lower end a broad flange or shelf. The larger cylinders are filled with cream of lime to about one-half their depth, which is kept in constant agitation by broad vanes *t t* attached to the spindle *u*, passing through stuffing boxes in the several cylinders. The gas entering the lower small cylinder by the pipe *o* depresses the liquid therein below the shelf, and then rises up through the fluid into the upper part of the outer cylinder; from whence it is conveyed by the bent pipe *v* to the second interior cylinder, and from it, in a similar manner, to the third, from which it escapes, as before described, to the outer cylinder, and from thence passes by the pipe *w* to the gasholder, or gasometer *x*, as it is commonly termed. The gasholder consists of a large outer cylindrical cast-iron vessel or trunk *y*, nearly filled with water, in which is inverted another cylinder *z* of sheet iron, a few inches less in diameter, and open at the bottom; the inner is usually suspended by a chain passing over pulleys, and having counterbalance weights attached to them, so as to allow the vessel to rise easily by the upward pressure of the gas upon its entering. For the purpose of suspending the inner vessel, a heavy frame, or bridge, was formerly erected over the whole; but a much superior method is now generally employed; in the centre of the vessel *z* is a tube of about three feet diameter, through which rises a cast-iron pillar 2 to a plate, on the top of which are fixed the balance wheels, the weights 3 3 rising and falling within the pillar. From the gasholder the gas is conveyed by the eduction pipe to the street mains, and from there, or from the various service pipes branching from them, it is conveyed, by small wrought pipes, to the street or private lamps. In order to regulate the flow of gas into the main, at the junction of it with the eduction pipe is placed a regulating valve, and from the main is supplied a lamp kept constantly burning, whilst an attendant, by partially opening or closing the valve, maintains the flame of the lamp at the proper height.

The engraving on the following page represents an improved description of regulating valve, which has been introduced at the Bath Gas Works by Mr. Eastwick, the engineer of that establishment. The valve consists of a circular

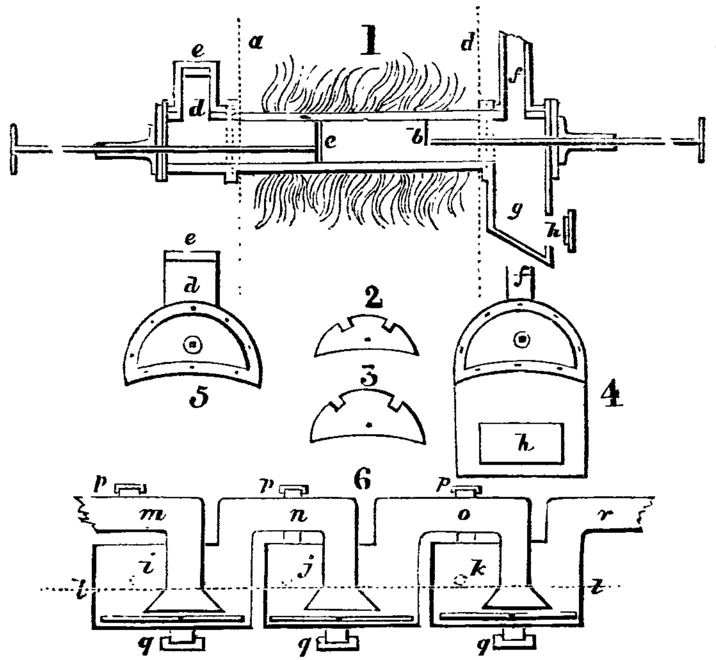
plate of metal, nine inches in diameter, sliding over the mouth of the main pipe in a chamber; the face of the index is a representation of the valve itself, so made in order that the superintendent may know the precise position of the valve at any time. The disc A is a thin plate of metal attached to a rod coming up from the valve behind the index frame, in which there is a slit for the pin, which carries the index, to pass. The portion of the circle B, which is uncovered by the disc, represents the aperture or gasway into the main pipe. G is a pressure gauge connected with the main on the gasometer side of the valve, and T another pressure gauge, also connected with the main on the town side; there is a burner supplied from the town side of the valve placed before the



eye of the person who adjusts the valve. From repeated inspection of the town lights at all hours of the night, as well as of the burner before the index, the requisite pressure is known and regulated; as the night advances, the valve is lowered more and more, and in the morning (when the lamps *ought* to be all out) it is depressed to one-tenth of an inch, that being sufficient to cause the exit of the gas in the lowest situations.

The opposite engraving exhibits a new construction of a retort and of a purifying vessel, for which Mr. Hobbins, of Walsal, in Staffordshire, obtained a patent. The objects sought by these new arrangements are, first, an increased facility of charging and discharging the retort without the necessity of luting the joints; and a more rapid decomposition of the coal, by spreading it in a thin stratum equally over the bottom of the retort; and the subsequent purification of the gas, without employing mechanical labour to produce a constant agitation with the lime or other purifying materials. *Fig.* 1 shows a longitudinal section of a retort, supposed to be placed in a furnace occupying the space between the dotted lines *a a;* the two ends of the retort are flanged on to the body, and, projecting beyond the brickwork, are removed from the influence of

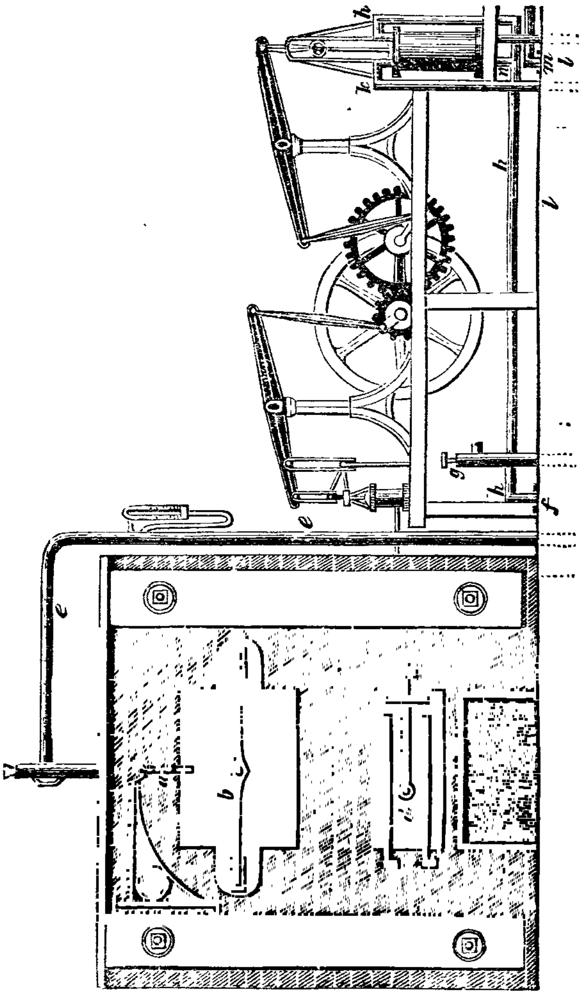
the fire; *b* and *c* are two scrapers, with long rods attached to them, which pass through the flanged ends of the retorts, and have cross handles at their extremities. From each end of the retort a tube projects horizontally, which serves to support and guide the scraper rods, which slide through them. The form of the scraper *b* is shown by the separate figure 2, and the form of *c* by *Fig.* 3; in each of them are two square notches, which, sliding upon square bars of iron, placed longitudinally on the upper side of the interior of the retorts, are thereby suspended to it, and kept uniformly in their proper positions. The process of working the retort is as follows:—previous to charging it, the scraper *c* is drawn outwards from the body of the retort close up to its end, and the scraper *b* is pushed inwards so as to come in contact with *e*; both scrapers being then beyond the opening *d*, the charge of coals is admitted through the latter by opening the cover *e*; the scraper *b* is then drawn back from its position beyond *d*, and thus spreads the coals in an even layer over the bottom of that part of the retort exposed to the fire. About a foot from each scraper, the rods are connected by a solid and a hollow screw, so that,



when the rods are drawn out, they may be renewed by unscrewing them at these parts. As the distillation of the coal proceeds, the gas escapes by the tube *f*, and from thence passes through the condenser to the purifying vessels. When all the gas has been separated from one charge of coals, the scraper *c* is thrust forward, pushing before it, and clearing out all the coke, which falls into the coke box *g*, from which it may be discharged by the mouth piece *h* into a barrow, and wheeled away. As it is necessary that the apertures at *d* and *h* should be closed air-tight during the extrication of the gas, the lids or doors are lined with lead, which, being screened from the heat of the furnace, serves to close the joints as effectually as the troublesome process of luting them at every charge. *Fig.* 4 gives an external view of that end of the retort where the coke is discharged, and *Fig.* 5 a similar view of that end at which the coals are put in; the letters have reference to the like parts in each figure. *Fig.* 6 gives a

vertical section of a series of three vessels, *i j k*, which constitute the purifying vessels; the lower parts of them are occupied with a stratum of lime as high as the dotted line *l l*; the impure gas passes from the retort into the tube *m*, and by its pressure descending along the bent arm, it passes out at the bell-mouthed end, and mixes with the lime contained in the vessel *i*, wherein it deposits much of its impurity by condensation; from this vessel the gas again rises and enters the tube *n*, thence filtering through the second lime vessel *j*, it reascends and enters the tube *o* into the third filtering vessel *k*; thence it proceeds by the tube *r*, to the gasholder, for subsequent distribution. The covered tubes *p p p* above the filtering vessels are for the purpose of charging them with lime; the dotted circles are perforations in the sides of the vessels (furnished with plugs) for the purpose of ascertaining the depth of the stratum of lime, or other purifying material; and the three tubes *q q q* at the bottom of the vessels are for discharging the lime when saturated with the various matters that have been condensed during the purifying process. To aid the complete discharge or clearing of these vessels of their contents, three bars of iron are employed as scrapers, one in each vessel, and a rod, as a handle, is screwed into each, and passes through a stuffing box in the side of each vessel. We are not aware whether the preceding apparatus has been adopted in practice. Retorts of a semicircular form in their transverse section have been tried, but although the coal was very rapidly and effectually decomposed, they were so speedily destroyed that we believe retorts of this figure are no longer employed. Upon the subject of retorts generally, it may be observed, that they, together with the hydraulic mains, and other necessary connexions, form one of the principal items of charge in the erection of gas works on the ordinary plan; and that in conducting works on the same principle, an enormous expense is annually incurred by the oxidizing or burning away of the retorts. Indeed the oxidation of these vessels is so rapid, that however the time of their duration may vary from a difference of their form, the quality of the iron, or the mode of setting them in the furnace, they cannot withstand, on an average, more than eight or nine months' wear. To avoid these sources of expense, and with a view to other advantages, Mr. S. Broadmeadow, of Abergavenny, devised the following process, which he secured by patent. The plan was adopted at the Abergavenny Gas Works, but has not come into use elsewhere; and although it may not realize all the advantages contemplated by the inventor, is deserving of notice in this place. The plan consists, first, in substituting brick ovens for iron retorts; secondly, in exhausting the ovens of gas, as fast as it is generated, by means of an exhausting cylinder, or any equivalent apparatus; and thirdly, in purifying the gas so generated, either wholly or partially, by admitting into the gasometer a certain portion of atmospheric air. The engraving on page 593, with the following description, will sufficiently explain the process; *a* is the oven in which the gas is generated; *b* the oven door; *d* door of the fire grate; *e* a pipe through which the gas is conveyed from the oven to the condenser *f*, into which a small hand-pump *g* is inserted to draw off the coal tar; *h* a pipe through which the gas passes from the condenser into the top of the exhausting cylinder *i*: the piston of this exhausting cylinder receives its motion from a small steam engine, which is supplied with steam from a boiler fixed in the flue, and heated by the waste fire of the furnace. *k k* two pipes, one leading from the top and the other from the bottom of the exhausting cylinder to the purifier *l*; *m* the outlet pipe to convey the gas from the purifier into the gasometer; and *n* is a pipe branching from the pipe *h* to convey the gas, at the alternate vibration of the beam, into the lower part of the same cylinder. Some ovens on this principle have, as we have already mentioned, been erected at the Gas Works at Abergavenny, and it is stated, that, after being kept constantly at work for two years, they were not apparently the worse for wear, whilst the charges for repairs had not reached twenty shillings each per annum. Another advantage is, that as these ovens contain a charge equal to about six full sized iron retorts, and require to be charged but once in twenty-four hours, there is not only a saving in the first cost of erection, and in the annual wear and tear, but in all the daily labour consequent upon the old

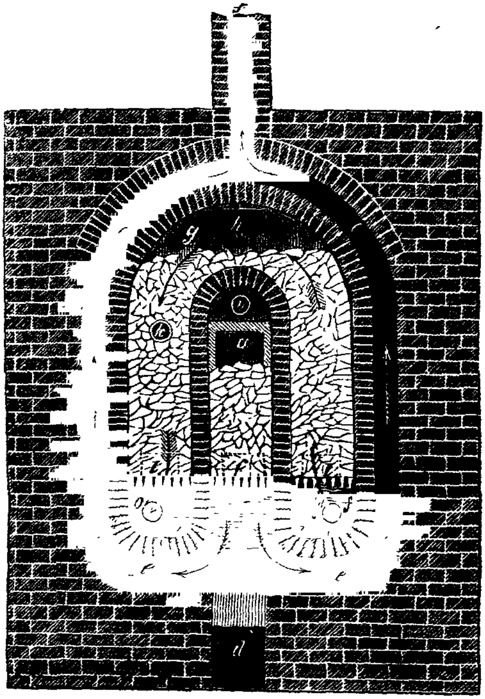
process, in which much time, as well as labour, is usually expended in the drawing off the charge, and in recharging.



The next improvement, and which indeed constitutes a principal feature in Mr. Broadmeadow's invention, is that of his patent application of an exhausting cylinder, or other apparatus, to exhaust the gas from the condenser, thereby causing a partial vacuum, and enabling the gas to flow from the ovens as fast as it is generated. By means of this exhausting apparatus a portion of atmospheric air, equal to about one-eighth part of the entire quantity of gas, is admitted into the gasometer, when the oxygen of the atmosphere mixing with the suphuretted hydrogen precipitates the sulphur, and gives to the lighted gas a greater degree of brilliancy. This mode of purifying gas is said, by the patentee, to be so efficient, that, when the coal used is of good quality, no other purifying process is required. As the admission of too great a quantity of

atmospheric air would prove injurious, the requisite speed at which the exhauster should be worked is shown by a water gauge.

We shall now proceed to describe Mr. Ibbetson's patent process of preparing inflammable gas by decomposing water, in conjunction with coal, in a furnace of a peculiar construction. The following engraving represents a vertical section of the apparatus employed. In the central compartment at *a* is an iron door and frame, opening above the fire-place for supplying the fuel thereto; immediately under the arched top of the fire-place is a small aperture *b*, for the admission of the air requisite for the combustion of the fuel; there is another small door, (shown by dots at *c*,) for the purpose of lighting the fire; *d* is the ash-pit, *e e e* is the flue which descends, and then takes the course pointed out by the direction of the arrows to the chimney, thus enveloping the decomposing chamber, which occupies the space between the flues and the central furnace. The coals or other substances to be decomposed are introduced through an

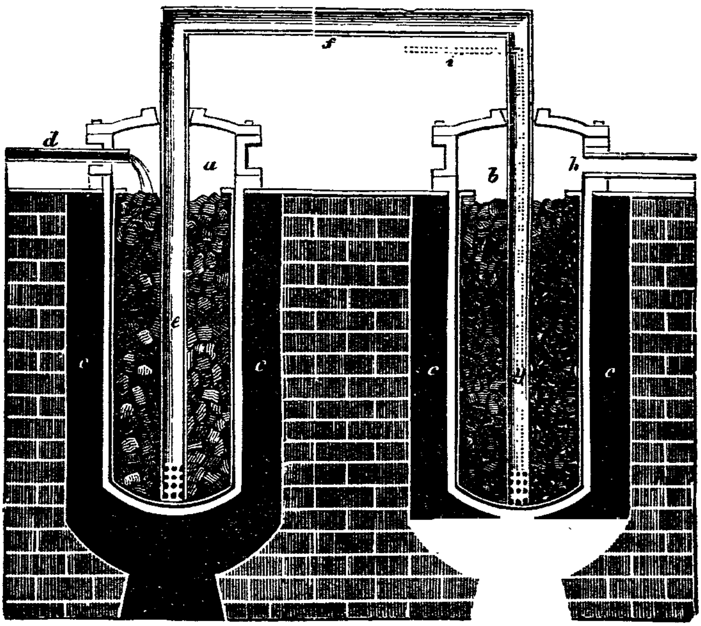


iron door *h*; this door, as well as the two other doors, *l l* (shown by dotted lines), for extracting the coke, are kept closed air tight, by luting, during the process of distillation; and for clearing out the ashes under the gratings, there are apertures at *i i*, fitted also with doors. and kept closed like the last mentioned, whilst the decomposition is going forward within. The steam is introduced at two places in the decomposing chamber; one at *f* by a pipe of retort earth, from whence it ascends among the ignited coke, passing round the chamber in the direction shown by the arrows; the other at *k*, where a tube of retort earth is extended across the chambers horizontally, the steam escaping from it through numerous small holes at the bottoms and sides. The gases and vapours produced by these combined circumstances make their exit by a pipe at *o*. By this apparatus, the patentee also professes to decompose tar and oil along with

the coal; in which case, these fluids would be introduced on the right hand side, (opposite to *k*,) through tubes, regulating the quantity by means of stop-cocks, which quantity should of course never be more than will become decomposed, whilst circulating through the burning coal, without reaching the bottom of that side where it enters. The patentee observes, that the coals should be broken into pieces not exceeding the size of walnuts, before they are put into the decomposing chamber; and that the charges should be made from time to time by fresh layers of an inch and a half in thickness, after the previous charge has become red hot.

We have already stated that Mr. Murdoch experimented upon wood and peat, as well as pit coal, in order to ascertain the qualities and quantities of illuminating gas furnished by each. Shortly after the introduction of gas lighting into public use, experiments were made upon various other substances, with the same view; as coal tar, pitch, pine knots, and sawdust; and in 1815 Mr. John Taylor obtained a patent for an apparatus for the purpose of preparing inflammable gas from any kind of animal, vegetable, or mineral oil, fat, bitumen, or resin, which can be rendered fluid by heat. The process may be briefly described as follows: the liquid material is allowed to flow in a very minute stream into a retort heated to redness, and containing a quantity of coke, hard broken bricks, or other porous and refractory substances; here the oil is speedily converted into a very fine and brilliant gas, which is conducted to a close vessel surrounded by water, in order to condense any oil which may have come over, not decomposed, or in the state of vapour, which oil is returned to the retort by a very simple arrangement. From the condenser the gas enters a vessel containing the liquid from which the gas is prepared, by which a further condensation of any condensible vapour which the gas may contain is effected, and the gas then passes into the gasometer.

Mr. Philip Taylor some time afterwards obtained a patent for an improved apparatus for obtaining gas from various substances in a liquid state, a section of which apparatus is exhibited in the following engraving. When the liquid



matter introduced into the retort is of easy decomposition, one distillation of it

through a single retort will be in general sufficient to separate the gas in a tolerably pure state; when they are, however, such as to require a longer process, the gaseous products of the first distillation are passed into a second retort, to complete the separation of the contaminating matter. As many as ten retorts similar to those shown in the engraving may be conveniently arranged over one furnace. In the case of a single distillation it is therefore to be understood that these are all supplied at once with the fluid matter, and the product of each retort respectively is carried from them direct to the gas holder; but when a second distillation is necessary, the ten retorts before mentioned would be employed as five pair, and the diagram is drawn so as to show the operation either by a single or by a pair of retorts, which we shall now explain. The figure gives a vertical section of two cast-iron retorts, *a* and *b*, fixed over a furnace constructed with fire-bricks; the retorts are about four feet long, of a cylindrical form, with covers accurately fitting their necks so as to render the vessels air-tight, when they are luted on and fastened down with keys or screws. They are placed erect in the brickwork by resting on their projecting flanges, leaving open spaces around them as at *c c c*, by which very extended surfaces are exposed to the direct action of the fire. Within each of the retorts a casing or shell of wrought iron is placed, exactly fitting the interior; these are filled with fragments of brick or coke, &c. and as these materials require to be frequently changed, each case is provided with ears or lugs, for the convenience of drawing them out, or letting them down into the cast-iron retorts. Vertical tubes, *e g*, are placed in the centre of each retort; they are connected at their upper ends by the horizontal tube *f*, and, passing through the covers, their other ends descend to the bottom of the retorts, when they are perforated with holes, as shown in the figure. The internal cases, previously empty, are then filled with broken bricks or other substances before mentioned, and the covers and joints being all properly luted and secured, the retorts are exposed to the action of the fire until the material contained in them acquire a red heat. Thus prepared for operation, the fluid to be distilled is allowed to flow through the pipe *d* in a small quantity into the retort *a*; here, falling upon the red hot materials, the process of decomposition commences, which is assisted by the filtration of the liquid through these substances. Having arrived at the bottom, the gaseous portion, passing through the perforations, rises up the tube *e*; thence, proceeding along the branch *f*, it descends into the second retort *b*, by the pipe *g*, and passing out again through the holes at the bottom of *g*, the gas reascends among the ignited materials, being purified in its progress, until it arrives at the tube *h*, which conducts it to the gasholder. When the operation consists of only a single distillation, the fluid is introduced by a pipe *i*, shown by the dotted lines. In this case the tube *g* does not extend higher than the cap of the retort, in the centre of which the pipe enters, and passes down the middle of the tube *g*, within six inches of the bottom; from thence the liquid, flowing through the perforations among the red hot materials, becomes quickly decomposed, and the resulting gas, filtering as it ascends, reaches in nearly a pure state, the tube *h*, which, as in the former case, conducts it to the gasholder.

Coal tar has already been noticed as one of the products resulting from the distillation of coal, and at the first establishment of public gas works, great profits were expected to be realized from the sale of this article; but from the large quantities produced, and from its inapplicability to most of the purposes for which vegetable tar is employed, it was soon found difficult to find a market, and it became an object to utilize the material by converting it into gas. For this purpose various processes were resorted to, nearly resembling that just described, for converting oil and other liquid matters into gas; but a serious inconvenience was found to result from the deposition of asphaltum in the pipes, (owing to the imperfect decomposition of the tar,) which quickly choked them up, and rendered them unserviceable, whilst the gas afforded but a feeble light, and emitted much smoke. Numerous plans have since been proposed for the remedy of these evils, of which we shall only notice the invention of Messrs. Vere and Crane; the apparatus, it is stated in the specification, is also applicable to the distillation of all animal or vegetable solid or liquid matters, from which

carburetted hydrogen may be obtained. The process consists in introducing into the retort a constant stream of water, or a current of steam into the exit pipe, which, mixing with the volatile matters arising from the substance under decomposition, causes them to fall down again into the retort without proceeding further to choke up the pipe, while the more gaseous products pass on through the steam in a purer state to their destination, to be afterwards treated in the usual way. *Fig.* 1 is a front elevation of the improved retort set in the brickwork of the furnace; and *Fig.* 2 is a vertical section of the same; the

Fig. 1.

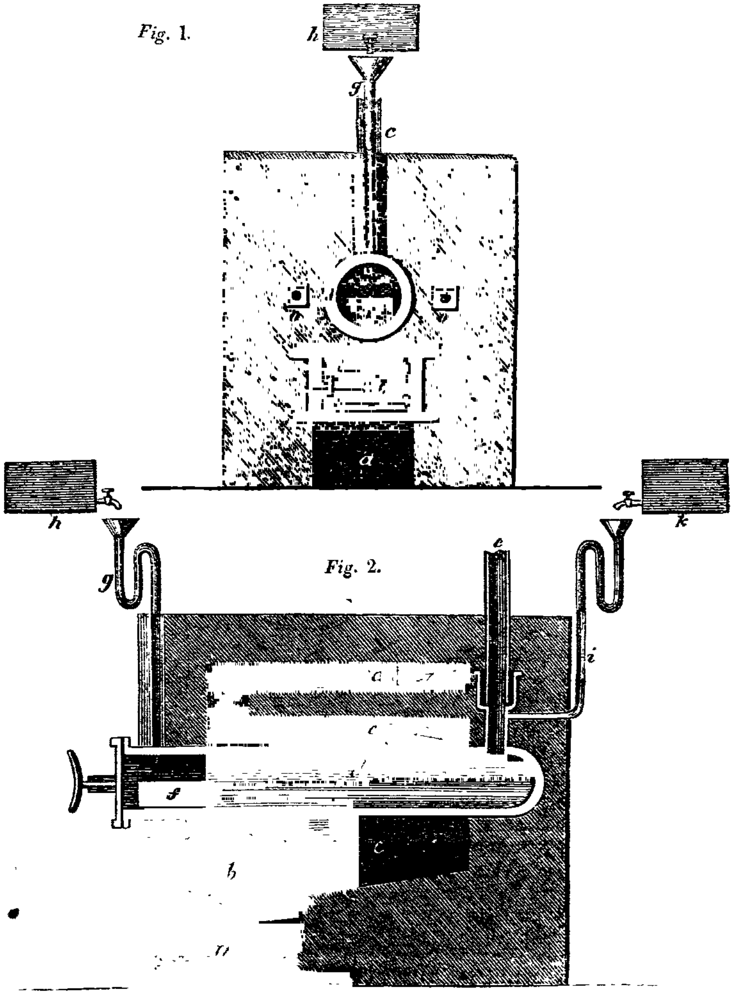
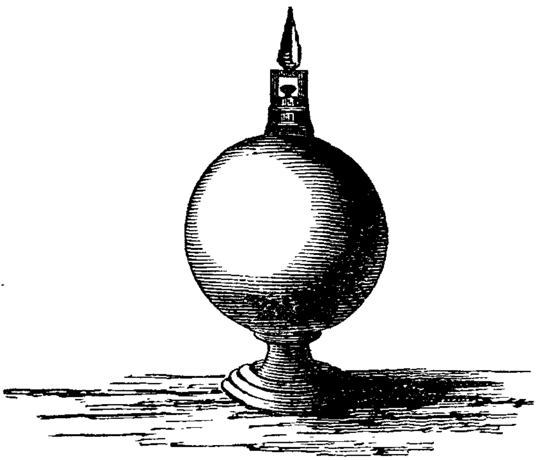


Fig. 2.

letters have a reference to the same parts in each figure. *a* is the ash-pit, *b* the furnace, *c c* the flue winding round the retort; *d* the retort, with its lid fastened in the usual way by a cross bar and screw; *e* the exit pipe, through which the gas escapes as it is generated; *f* is a wrought-iron pan or tray, to hold tar or other liquid matter to be distilled; *g* a supply pipe to *f*, leading from the cistern or reservoir *h*; *i* is a water pipe, and *k* a cistern of water.

When tar, for instance, is to be operated upon, the retort, partly filled with coke or broken bricks, is to be brought to a bright red heat, which may be ascertained by inspection through the holes *o o*, shown in *Fig.* 1, which are provided with stoppers; the cock of the water pipe is then opened, to admit the water to flow in a slender stream into the retort, the heat of which immediately converts it into vapour. This done, tar is to be admitted from the reservoir *h* to flow through the pipe *g* into the pan *f*, where it is quickly decomposed; the gas, as it ascends, enters the exit pipe, and necessarily passes through a large volume of steam, which, the patentees state, causes an instant precipitation of the carbonaceous matters, which would otherwise lodge in the pipes, and ultimately obstruct the passage of the gas through them. The gas thus relieved in the earliest stage from the principal contaminating matters, has then to pass through the ordinary purifications, by which it is ultimately delivered to the burners, in a state of great purity, for consumption. When coal or other solid matters are to be decomposed to obtain the gas, the pan *f*, the pipe *g*, and the reservoir *h*, are to be removed, and the operation conducted without them, retaining however the use of a current of steam as before.

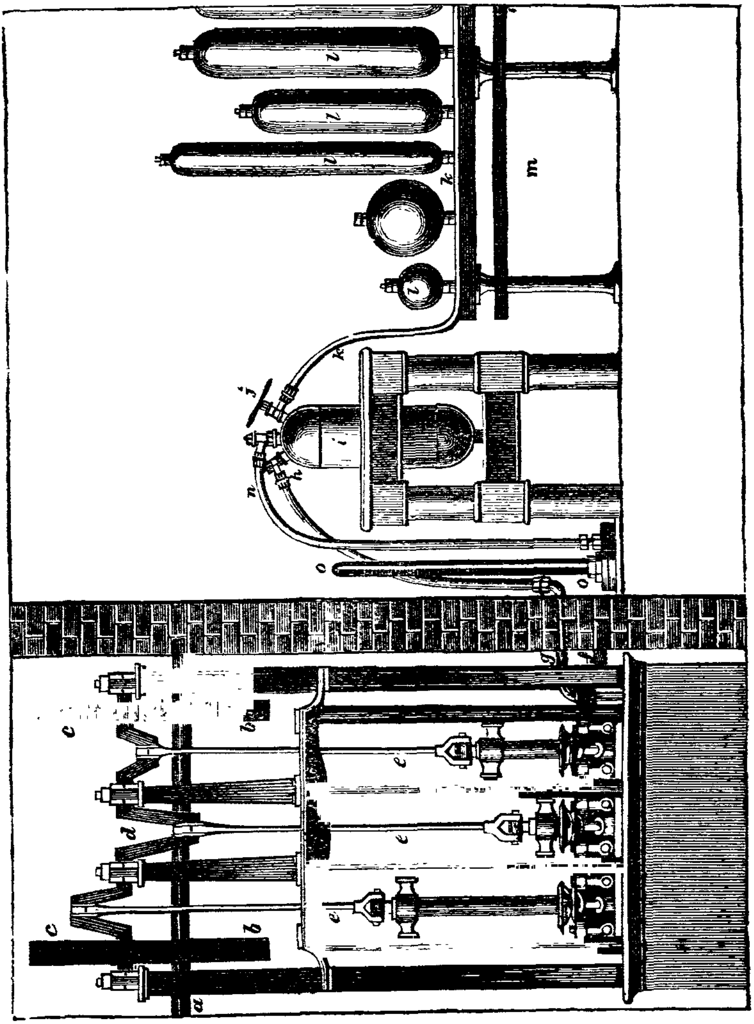
The subjoined engraving represents Mr. Gordon's portable gas lamp. The idea of employing gas as a substitute for lamps and candles, occurred to Mr. Murdoch, as we have seen, so early as the year 1792, when he made



some experiments with that view, but seems to have subsequently abandoned the idea; but to Mr. Gordon is due the merit of realising it, and thus at length rendering inflammable gas applicable to every purpose of artificial illumination. These lamps consist of strong wrought-iron vessels of various dimensions and forms, in which the gas is compressed into one thirtieth of its bulk at the ordinary atmospheric pressure; the flow of the gas being regulated with the utmost exactness, according to the degree of light required, by a valve, which we shall subsequently describe.

A company having been formed to carry Mr. Gordon's invention into effect upon an extensive scale, works have been established in London, and at some of the principal country towns, at which the gas is manufactured; and the lamps being charged therewith, are furnished to the consumer as occasion requires. The gas with which the lamps are charged is usually procured from oil, on account of its greater purity, and of its occupying less space than coal gas, one foot of oil gas being equivalent in illuminating powers to nearly three feet of coal gas. The gas is generated by the usual processes, and the following engraving represents the apparatus employed at the London Portable Gas Works for charging the lamps; *a* is the main horizontal shaft of a steam engine, upon

which are fixed two spur wheels *b b*; the teeth of these take into the teeth of two similar wheels *c c* fixed on the axis of a three-throw crank, to which is thereby communicated a rotatory motion. The crank imparts (in the usual manner) an alternating motion to the rods *e e e*, which work three force pumps: for a description of the forcing pumps originally employed for this purpose, (which were of a singularly ingenious construction, although we believe they have since been replaced by others more nearly resembling the ordinary

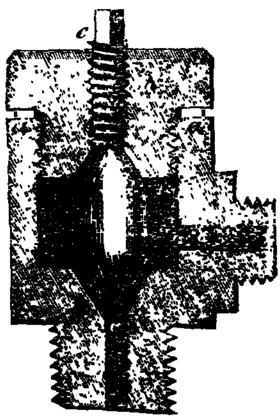


force pump,) we refer the reader to the article Air Pump. As the plunger of each pump is successively raised, a quantity of gas equal to the space previously occupied by the plunger flows from the gasholder into the chamber at the opposite end, by means of a pipe of communication, part of which is brought into view at *f*. The valve by which the gas enters, opens *inward*, so that it cannot return the way it came; but there is another valve which opens

outward, and this is kept closed by a spring of sufficient power to prevent the escape of the gas in the uncompressed state; upon the descent of the plunger the strength of this spring is overcome, the gas is forced out, and the valve closes again. From the pumps the gas proceeds along the tube *g*, and enters by the jointed valve *h*, into a strong wrought iron recipient *i*; in this vessel it is evident the gas might be collected and condensed to any required number of atmospheres; but the valve *j* being opened (by the cross-handled key shown), the gas is suffered to flow through the pipe *k k*, which is extended along the upper side of the "filling table" *m*, and from thence into the reservoirs ("portable lamps") *l l l l*, by which arrangement the pressure of the gas becomes equalized in all the vessels, however great their number. The degree of condensation at which the gas has arrived by the continued action of the pumps, is shown throughout the process by a mercurial guage, applied in the following manner. The pipe *n*, which proceeds from the recipient *i*, conveys the gas under compression into the reservoir of mercury, at the bottom of the guage *o o*; the pressure of the gas upon the surface of the mercury causes the latter to rise in a long glass tube, hermetically sealed at top, and inclosing a portion of atmospheric air above the surface of the mercury; this air becomes compressed into a smaller space by the rise of the mercury, as the condensation of the gas advances, and the diminution of its volume indicates, upon a scale attached to the tube, the degree of condensation or pressure in the lamps; and when the mercury arrives at the line denoting thirty atmospheres, the valve *j* is shut by means of the cross handle. All the lamps attached to the pipe in connexion with the closed valve being now filled, are taken away by unscrewing them from the sockets in the tube. The external pressure being removed by turning off the gas, the lower valves of the lamps close by the pressure of the gas within them, and the contents are further secured from escaping by a workman screwing a cap over the lower valve as he successively removes each of them from the tube. To ascertain whether there is any leakage, the lamps are immersed one by one in a contiguous trough of water, where, if any leakage exists, it is immediately shown by the gas bubbling up. The perfect state of each lamp being thus ascertained, they are arranged in extensive racks or stands, ready to be taken out to the consumers by the Company's carts, which are regularly dispatched to all parts of the town.

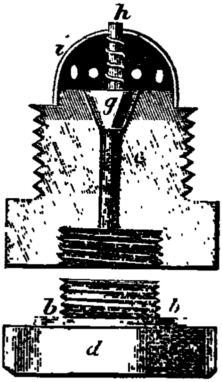
To complete the subject, we shall proceed to describe the *construction* of these valves, of the *uses* of which we have only yet spoken: they are of three kinds, and were the subject of a patent granted to Mr. Gordon.

The annexed engraving gives a sectional view of an improved stop-valve (similar to those attached to the principal recipient *i*), especially adapted for transferring the compressed gas from one vessel to another, without occasioning loss during the process. It is composed of two pieces of metal, A and B, which are screwed together with a soft metal collar between them at *a a*; *e e* represents the openings through which the gas is allowed to pass. The piece A has the regulating steel screw *c* tapped through it, being formed at the lower part with a double cone, one part of which cone is adapted to fit correctly into the cavity in the under side of the piece A. Now when the lower cone of the regulating steel screw is screwed or forced tight down into the conical seat in the piece B, it prevents all escape of the gas; and when it is desired to transfer compressed gas from one lamp or reservoir to another, the regulating screw *c* is to be turned until its upper cone fits and applies correctly into the conical cavity of the piece A, and thereby prevents all escape of the gas up the threads of the regulating

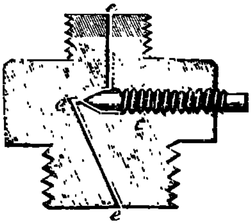


screw during the process of transferring, allowing, at the same time, free passage of the gas from one reservoir to another, through the openings *e e*.

The next valve to be described is the one which is fixed at the bottom of each reservoir or lamp, for the purpose of filling them in the manner described in the preceding part of our subject; the annexed cut represents a section of one of those valves. This filling valve consists of a small conical plug *g*, which is fitted into a conical cavity or seat in the piece of metal *c*, similar to the valves of an air-gun, being closed by a slight steel spring *h*, and guided in its way by a metal pin, which slides through a hole in a small brass cap or perforated cover *i*, represented as screwed over it; *d* shows a brass plug, which is intended to be screwed into the lower aperture of the piece *c*, after the filling is completed. The upper surface of this screw-plug is furnished with a soft metal ring or collar, *b b* (as in the before-mentioned valve), which being pressed, by the force of the screw, into contact with the under side of the piece *c*, effectually prevents any escape of the gas from that end of the reservoir, even if the filling valve *g* should not be quite air-tight.



The following figure represents a section of the third and last of these valves, and its use is to permit the flow of gas to the burner to be regulated with great nicety and precision. The passages for the gas, *e e*, are drilled out of one solid piece of metal, and the regulating screw *c* is tapped into the side of the same piece; the lower part of it is adapted to screw into an aperture at one end of the reservoir of the lamp, when the regulating steel screw *c* is screwed up so that its conical end fits tightly into the conical cavity,—it closes it perfectly, and prevents all escape of gas to the burner *a*; but on turning the regulating screw slightly round by its square head, the gas escapes through the passages *e e* to the burner, in any degree that may be desired. Previously to inserting the regulating screw, it is dipped into a mixture of bees' wax and oil, which fills up every minute cavity or space which may be left between the threads of the two screws.



The engraving on page 602 represents a contrivance for delivering gas to the consumers in its natural volume, under atmospheric pressure. It consists of a collapsing gasholder, capable of containing upwards of 1000 cubic feet of gas; it is mounted on wheels; and being charged at the gas works, the gas is conveyed wherever required. The invention forms the subject of a patent to Messrs. Coles and Nicholson, and is, we believe, made use of by the Portable Gas Company at Manchester, in addition to the gas-condensing apparatus erected at their works at that place. *Fig.* 1 represents a plan of the cart, with the top of it removed; *Fig.* 2 is a side elevation, and *Fig.* 3 a front elevation; *Fig.* 4 is merely an enlarged section of the box marked *d* in *Fig.* 2. The recipient is composed of two distinct parts or halves, *a* and *b*; the upper part *a* is made of some flexible material, impervious to gas; and the lower part *b* of some comparatively stiff and inflexible substance; when the vessel is empty, the part *a*, turning itself inside out, falls down inside of *b*; the vessel is filled by forcing the gas from the works through a pipe, which is screwed into a nozle at *f*, provided with a stop-cock, which is turned off after the recipient is fully inflated, and the supply pipe from the works removed. The machine then travels through the streets, and stopping at a customer's door, one end of a flexible

pipe is screwed into the gasholder of the house, and the other end into a nozle in the box *d*, which communicates with the interior of the recipient by means of intermediate valves shown at *Fig.* 4. The gas-exhauster *c* is then put in motion by the handle at the top, and at every exhausting stroke is filled with

Fig. 1.

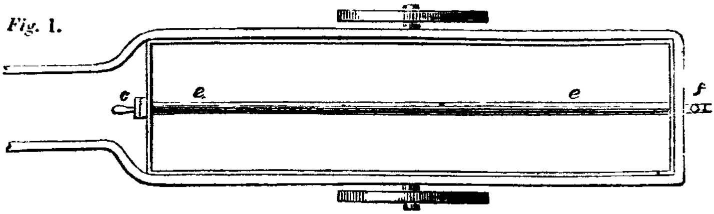


Fig. 2.

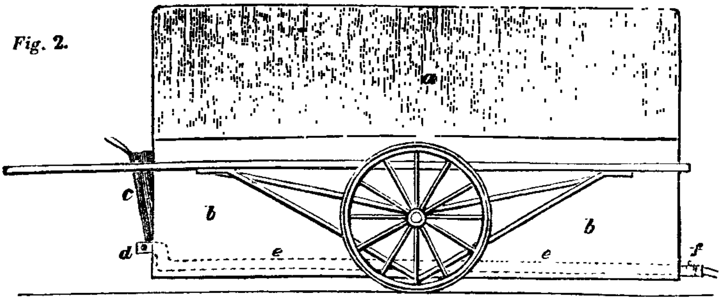


Fig. 3.

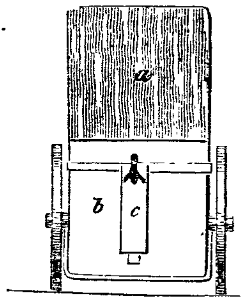
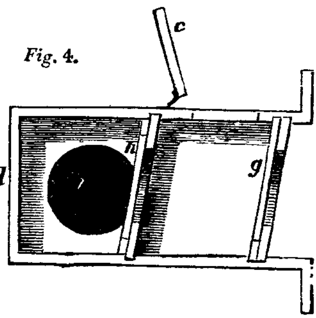


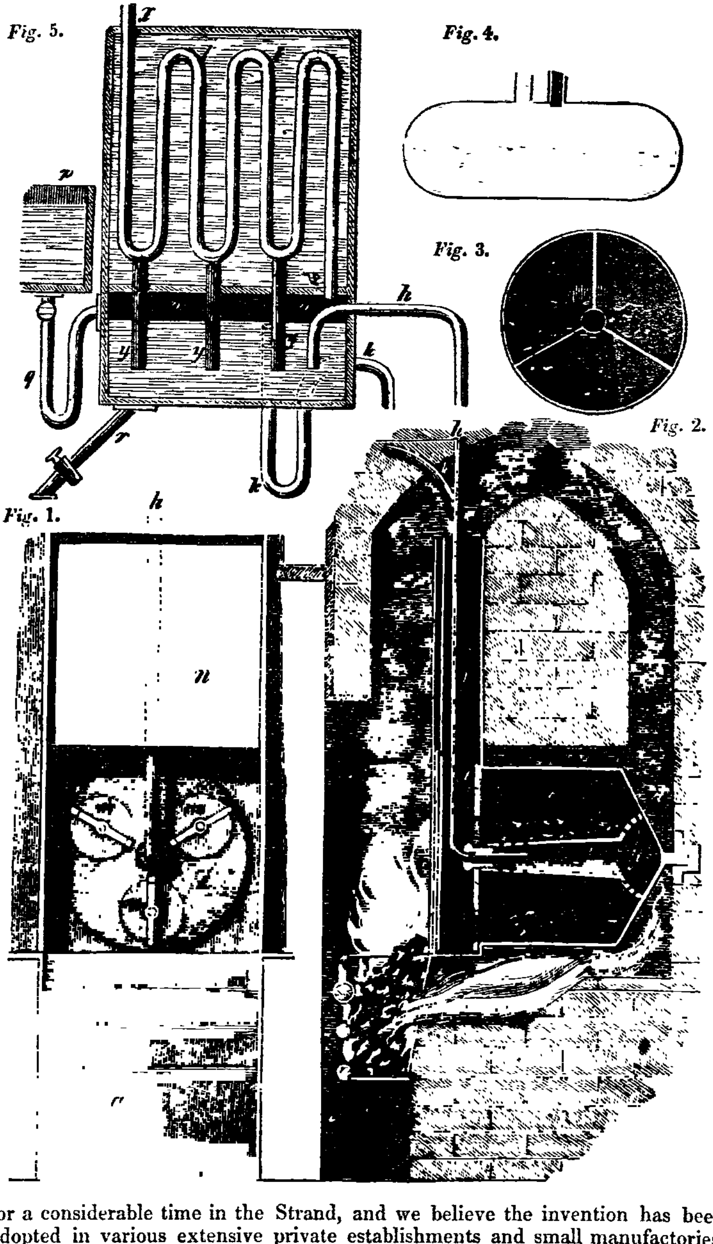
Fig. 4.



gas from the gas cart through the valve *g*, *Fig.* 4; and at each forcing stroke, the gas is discharged through the valve *h*, and along the flexible pipe into the gasholder of the house, until the required quantity is transferred. The gas cart thus proceeds from house to house, until the whole load is discharged. Along the bottom of the cart is a pipe *e*, connected at one end with the stop-cock *f*, and at the other with the box *d* of the exhauster, and perforated with numerous small holes, for the purpose of allowing the passage of the gas along the bottom of the cart when the flexible top lies over it. Since the foregoing account of the Portable Gas Machinery was prepared for the press, we have been informed that it has been nearly superseded by subsequent improvements in the manufacture and management of *coal* gas; nevertheless, the subject possesses sufficient intrinsic merit for our pages, as much of the mechanism is applicable to other purposes.

The "Domestic Gas Apparatus," shown in the following engraving, is an

invention of Mr. Pinkus, for the manufacture of gas on so small a scale as to be adapted to private houses. An apparatus of the kind was exhibited in use



for a considerable time in the Strand, and we believe the invention has been adopted in various extensive private establishments and small manufactories. *Fig.* 1 is a front elevation; *Fig.* 2 a lateral section of the apparatus; *Fig.* 3 a section of the retort; and *Fig.* 4 a section of a retort of a different construc-

tion; *Fig.* 5 is a section of the condenser. In each bottom figure the same letters refer to the same parts. *a, Figs.* 1 and 2, shows its application to a kitchen range, but it is equally adapted to any other common fire-place; *b b, Fig.* 2, is a recess or furnace built in brick at the back of the fire-place, covered in front by an iron plate *c*, and having a flue *d* opening into the chimney; *e, Figs.* 1, 2, and 3, is a cylindrical retort, divided by two or more internal partitions, radiating from a conical pipe *f*, as shown in *Fig.* 3. The retort is turned with a small rim or flange at the fore end, which fits into the plate *c*, and the hinder end is supported by a stout pin projecting from the back of the retort, and resting in an iron socket let into the brickwork. The hinder end of the pipe *f* terminates in a cup or cavity *g*, pierced with several holes, and serving as a chamber for the gas to collect in; the pipe *f* is also pierced with numerous small holes, to allow the tar, as it forms, to fall through them upon the burning fuel, where it, as well as that portion which runs down the conical pipe *f* and the cup *g*, is decomposed and converted into gas. In the fore end of the pipe *f* is screwed a stuffing box, through which passes the pipe *h*, leading to the condenser. Each compartment of the retort has a door or mouth-piece *m m*, by which the coal or other material for making gas is introduced, and the door is secured by screws, the joints being either ground true or luted; *n* is an iron plate, sliding in grooves, and, when lowered down, serving to defend the face of the retort and the pipe *h* from the action of the fire. *Fig.* 5 is a vessel divided into two parts, the lower part *o*, which is air tight, containing a quantity of tar, into which the pipe *h* dips a few inches; it is supplied with tar from another vessel *p*, by means of a bent pipe *g; r* is a pipe for drawing off the tar when required, and *s* an opening by which the tar runs down the pipe *k* into *h*, and thence into the retort. The upper division of *Fig.* 5 contains a range of bent pipes *t t* surrounded by water, one end of which, *v*, opens into *o*, and the other end, *x*, leads to the gasometer; from the lower bends of these pipes short pieces *y y* descends into the tar in *o*, by which means the tar condensed in the pipes *t t* descends into *o*, whilst the gas cannot escape through the short pipes. The operation is as follows:—the retort being charged, and the doors secured, the retort is turned till the chambers are in the position shown in *Figs.* 1 and 3; the shutter *n* is then let down and the fire lighted, a portion of the heat and flame from which passes through an aperture in the back of the range (shown by the black space between the bars in *Fig.* 1,) into the furnace *b*, causing, in a short time, the lower part of the retort to become red hot, and the coals or other materials in the interior to give out gas, which, collecting in the chamber *g*, passes through the pipes *f* and *h* to the condenser; at the same time the tar given out by the coals in the upper chambers of the retort, descends through *f* and *g* on to the burning fuel in the lower chamber, and becomes decomposed. When it is supposed that the materials in the lower compartment have given out all the gas contained in them, the retort is turned partly round, so as to bring another compartment immediately over the flame, when the gas is again given out as before. The gas thus formed contains tar and other impurities, from some of which it can be freed by a reduction of temperature; the pipe *h* is therefore made to dip a few inches into the tar vessel *o*, and through this tar the gas has to rise to enter the condenser, by which means it is divested of a portion of its impurities, and, upon entering the condenser, it passes through a great length of pipe surrounded by cold water, when all the *condensable* impurities are separated, and descend into the tar vessel by the pipes *y y*. The tar, as we have before stated, returns to the retort by the pipes *k* and *h*, and is decomposed by falling on the burning coke in the retort. From the condenser the gas passes to the purifier, and thence to the gasholder; but the method of purifying the gas, either upon a large or a small scale, forms the subject of a separate patent to Mr. Pinkus, which we shall now proceed to describe, observing only that *Fig.* 4, in the preceding engraving, merely represents an oblong retort, which may be substituted for the one before described, when the length of the fire-place will admit of it; it will then of course be fixed, instead of turning upon a pivot, and the gas will pass off by the pipe *h*, and the tar return by *k*, inserted in the top of the retort.

The purifying substances employed by Mr. Pinkus, are the chlorides of soda or of lime. The following engraving represents two arrangements of the purifying vessels; the one adapted to the use of gas works on a large scale, and the other for the use of private houses, to purify the gas as it passes from the public main to the burners. The method is as follows: the gas, upon leaving the condenser, passes through a solution of the chlorides of soda or of lime, which may be contained in a vessel resembling that shown in section at *Fig.* 1, through which the gas may be made to pass, acting under a pressure

Fig. 2.

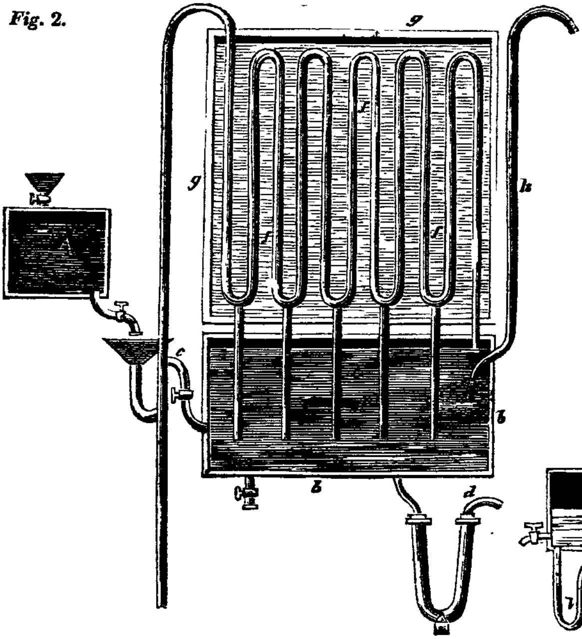


Fig. 3.

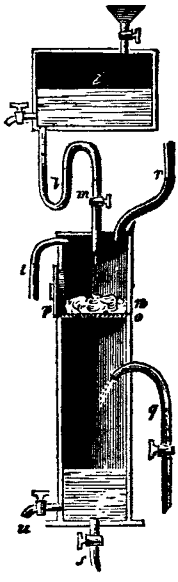
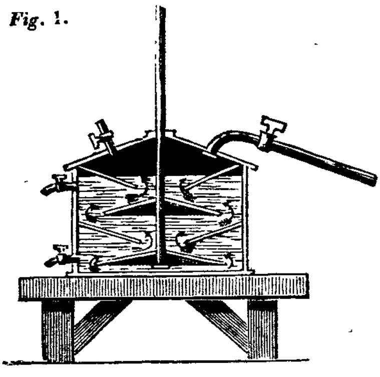


Fig. 1.

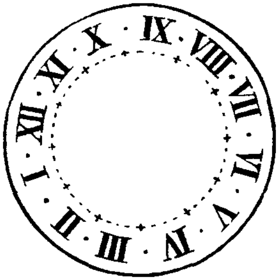


of from ten to twenty inches of water, by which means it will be purified, and its obnoxious odour and bad smell removed; in addition, the patentee recommends to pour a quantity of the same solution into the feeder A, *Fig.* 2, from whence it flows into the tar vessel *b b b*, through the bent tube *c*. In this vessel, (which communicates with the retort by the pipe *d*,) the solution will mix

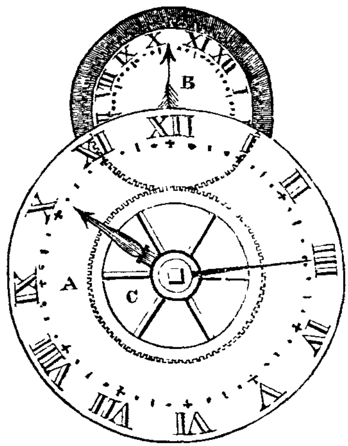
with the condensed matter that falls into it through the branch pipes connecting the refrigerator tubes *f f f*, (which are immersed in a vessel of water *g g*,) with the tar vessel. The compound thus formed, and kept agitated by the gas issuing from the dip pipe *h h*, is made to flow in a small stream through the pipe *d*, into the retort, while in action; upon coming in contact with the ignited materials within the retort, other vapours or gases will be generated, which, combining or mixing with the carburetted hydrogen gas, a chemical action will take place, whereby the gas, while in the retort and during its passage through the refrigerator, will become partly purified, or will be so altered as to be more easily acted upon in its passage through the solution of the chloride of lime, when its purification will be finished. In preparing the solution, the patentee directs to employ one part of chloride to about thirty-five parts of water, and when the chloride is in its most concentrated state a diluted acid, sulphuric or muriatic, may be added to the solution to assist the liberation of the chlorine gas from the lime; and the quantity of water may then be increased to forty or fifty parts, with one of the chloride. *Fig.* 3 represents the apparatus for the more perfect purification of the gas on its passage from the street mains to the burners. *i* is a recipient, intended to contain and supply the purifying liquid; this vessel is connected with another vessel *k* by a syphon or by a bent tube *l*, inserted through the centre and top of the lower vessel *k*, and having a stop-cock *m*. The lower vessel *k* is made gas tight, and formed of tin, copper, or sheet iron, and is a receptacle for gas, which flows through it, and for the purifying liquid that falls from the upper vesel *i*; *n* is a common sponge placed on a shelf of coarse wire gauze *o*; *p* is a manhole made in the side of the vessel *k*, sufficiently large to admit the hand and sponge; *q* is a pipe leading the gas from the main; and *r* is another pipe to supply the gas in a purified state to the burners; *s* is a waste pipe to let off the liquid when it has become too much impregnated with the impurities of the gas; and *t* is a washing pipe leading from a cistern; *u* and *v* are stop cocks for admitting and drawing off the liquid. The operation of this apparatus is as follows: into the recipient *i* pour a mixture of one measure of the concentrated liquor of the chloride of lime, diluted with from twenty-five to thirty measures of water. When gas is required to supply the burners, turn on at the same time the stop-cocks *m*, in the bent tube *l*, and the leading pipe *q*; the purifying liquid will then flow through the bent tube *l*, on to the sponge *n*, which will absorb a portion sufficient to keep it always wet, and will permit the liquid to filter through, and fall to the bottom of the vessel *k*; at the same time the gas will continue rising through the moistened sponge *n*, where it will be acted upon by the purifying liquor, and its obnoxious odour will be removed before it arrives at the burners through the supply pipe *r*.

One object of great convenience and utility to which gas lighting has within these few years been applied, is the illumination of public clocks. This we believe was first put in practice at Glasgow, where a clock with two faces, supported at the extremity of a projecting bracket, was lighted by jets placed above it, the light of which was reflected on each face from mirrors placed within the wings of an elegant representation of a phœnix, which surmounted the clock. In order to light the burner without sending up a person for that purpose, in addition to the pipe which supplied it with gas, was another extending from the main to the burner, having a stop-cock at its junction with the main, and being perforated with numerous small holes throughout its length. Upon opening the cocks, the gas flowed through both pipes, and issued at the small holes in the *flash pipe* as it was called; and a light being applied below, quickly communicated along the whole length of the flash-pipe, and upon reaching the jet, ignited the gas issuing from it; after which, the cock on the flash pipe was shut. Various methods have since been proposed of lighting up clocks, one of which is as follows: a dial plate, out of which the figures representing the hours are cut, in contrary succession to the usual representation of them, is made to revolve on the axis that would otherwise receive the hour hand. Behind it is a solid field, out of which a sufficient space is cut to show the hour, half hour, or quarter; each half hour is repre-

sented by a star, and each quarter by a dot; and the time is reckoned by the hours and quarters which have passed the centre of the opening Behind the revolving plate is placed a gas light, which is ignited by the jet of gas being directed on to a piece of spongy platina.



A somewhat superior method to the preceding is exhibited in the following engraving. A is the dial plate of a common clock, with the hours, &c. marked upon it, as usual; B is the proposed addition to it, for the purpose of exhibiting the time distinctly during the night; C is a light cog-wheel, placed immediately behind the day dial; having its centre fitted in the arbour of the hour hand, and revolving with it. The night dial B is designed to be made of plate glass, with the hours painted upon it in black, and to revolve on an axis in its centre. The index represented by an arrow is fixed. The periphery of the glass plate is encompassed by a rim of brass, having cogs in its outer edge, which fits into the cogs of the wheel C; consequently they move together, and being of equal diameters, they perform their revolutions in equal time. The time represented in our engraving, is a quarter past X; when the hour hand has moved on to XI. (for instance), the transparent dial B will have moved an equal space past the fixed index, and denote the same precise time. Both dials must, by this simple contrivance, invariably agree in their respective indications of the time. During the day, the time is observed on the large dial as usual; and at night a lighted lamp placed behind the transparent dial will always exhibit the time as distinctly.



But the most perfect and ingenious mode of illuminating public clocks which has come under our notice, is that by which several of the church clocks in London are lighted. By the revolution of the hands, and the addition of only one wheel and pinion to the clock, the gas is lighted and extinguished at regular stated hours, which hours may be varied monthly to suit the increase or decrease in the length of daylight, by simply adding or withdrawing a pin. The inventor is Mr. Paine, from whose account in the Transactions of the Society of Arts we have taken the following abbreviated description.

Reference to the Engraving.—Fig. 1 represents a skeleton frame dial, cast all in one piece; the eight central divisions are very thin, and curved, so as not to coincide or interfere with the hands while passing over them; the spaces are all filled up with transparent red glass, ground rough on the inside. This by day is sufficiently dark to relieve and render distinctly visible the gilt hour numbers;

but at night, when the gas burners behind the dial plate are lighted up, the hours, minutes, and hands appear black, and the rest of the dial glows with a dusky red light. *Fig.* 2 is a horizontal section across the aperture *a a* in the church tower at the back of the dial *b b*; *c* the tube which carries the hour hand, having a balance weight and the wheel 48 on its inner end; through this passes the shaft *d d*, holding at one end the minute hand, and at the other end the pinion 14 and balance weight *e*; *f f* two gas burners; *g g* the tubes supplying the gas; the aperture *a a*, not being so large as the dial, is chamferred off at *i i*, to give a clear passage from the lights all over the dial; *j j* a curved reflector, made of sheets of tin; *k k* a bar crossing the aperture *a a* within, to support the motion wheels, and the additional twenty-four-hour wheel, 96; the long axis *d d* receives motion from the clock (as usual) by a bevel wheel; 14, 42, 12, and 48, *Fig.* 3, are the usual motion wheels and

Fig. 1.

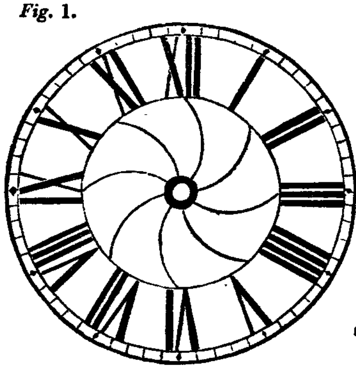


Fig. 2.

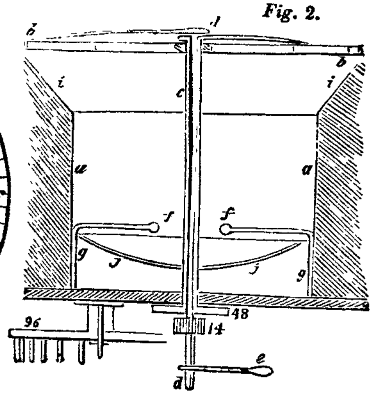
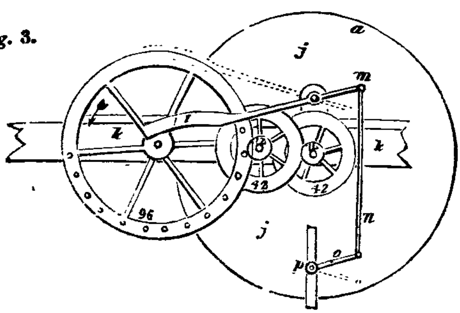


Fig. 3.



pinions; an additional pinion of 12 is put on the wheel 42, to turn the wheel 96; this has thirteen pins, one hour's motion apart; these pins raise up the weighted lever *l*, in *Fig.* 3, and let it drop; while this is up, (as shown by the dotted lines,) its opposite end *m*, by means of the connecting rod *n*, keeps the lever handle *o* of the gas cock *p* down, and thus nearly closes it, allowing the passage of only just enough gas to keep the burners alight; but at eight o'clock, when the weight *l* drops, it raises the handle *o* and quite opens the cock *p*, by which the dial is instantly illuminated. Thus, *Fig.* 3 represents the lever *l* down, and the pins nearly beginning to raise it; by removing two pins, one at each end, the clock will open the gas-cock one hour sooner, and nearly close it one hour later. By successively removing the pins as the days shorten, and replacing them as the days lengthen, the clock is accommodated to all seasons. The whole space is kept clear between the lights and the dial, except only the

axis *e*, *Fig.* 2; and the lights being placed on each side of this, and having a large reflector, no shadow is perceived from it.

With respect to the quantity of gas obtainable from a given weight of coal, it depends greatly upon the quality of the coal, and also upon the construction of the retorts, and the method of working them. Mr. Peckston, in his valuable treatise on gas lighting, whilst writing on this branch of the subject, observes that pit coal may be divided into three classes, according to the proportions of its component parts. Such coals as are chiefly composed of bitumen are to be considered as belonging to the first class. These coals burn with a bright yellowish blaze during the whole process of combustion; they do not cake, neither do they produce cinders, but are reduced to white ashes. At the head of this class is to be placed Cannel coal; and most of the varieties of Scotch coal, as well as some of those found in Durham and Northumberland, belong to it, likewise the coals from Lancashire and the north-western coasts of England. When ellipsoidal retorts are used, (which is the form which Mr. Peckston decidedly prefers,) and charged with $1\frac{1}{2}$ bushel, or about 126lbs of coal, the following quantities of gas may be obtained in the manufactory, or on the large scale. From a ton of

Lancashire Cannel	11,600 cubic feet of gas.
Newcastle (Hartley's)	9,600 „
Staffordshire (best kind)	6,400 „

The coke obtained from coals of this class is in small quantity, and of very inferior quality. The second class of coals comprehends those varieties which cake in burning. These contain less bitumen and more charcoal than the first class. They produce less ashes, but afford hard grey cinders, which when burnt over again with fresh coals, produce a very strong heat. The gas obtained from these coals is not of so rich a quality as that from the first class, but the coke is extremely well adapted for domestic and culinary purposes. When ellipsoidal retorts are used, charged as before, with about a bushel and a half, from a ton of

Wallsend, may be obtained . .	10,300 cubic feet of gas.
Temple Main	8,100 „
Primrose Main.	6,200 „
Pembry	4,200 „

The third class of coal consists of such as are chiefly composed of charcoal, chemically combined with different earths, and containing little or no bitumen. Amongst the varieties of this coal are the Kilkenny coal, the Welch coal, and the stone coal. None of the coals comprised in this class can be profitably used for making gas.

Mr. Peckston gives the following table, exhibiting the comparative quantity of gas obtainable from the following different species of coals comprehended in the first and second classes, the Scotch Cannel coal being considered the standard, and estimated at 1000.

Scotch Cannel.	1000	Temple Main	690
Lancashire ditto	986	Manor Wallsend . . .	650
Yorkshire ditto	949	Forest of Dean — Middle Delf	612
Bewicke and Craister's Wallsend	875	Eden Main	562
Russell's ditto	861	Staffordshire coal, 1st kind	546
Tanfield Moor.	850	Ditto ditto, 2d ditto	514
Heaton Main	822	Ditto ditto, 3d ditto	492
Hartley's	810	Ditto ditto, 4th ditto	490
Killingworth Main . . .	792	Pembry	354
Pontops	762		

With respect to the best form of retorts, and the mode of working them, so as to produce the largest quantity of gas, we give the following summary of three sets of experiments detailed in Mr. Peckston's work; the coals in each instance were of the same quality. 103 chaldron 12 bushels, distilled in

circular retorts, charged with 2 bushels of coals, and each charge worked off in 6 hours, afforded 8300 cubic feet of gas per chaldron, and required 43 chaldron 14 bushels of coals for heating the retorts, = 42 per cent. on the quantity employed for making gas. By cylindrical retorts charged with 2 bushels at each charge, and which was worked off in 8 hours, 85 chaldron, 27 bushels of coals yielded 10,000 cubic feet of gas per chaldron, and required for carbonization or heating of the retorts 21 chaldrons 16 bushels of coals, or about 25 per cent. of the quantity carbonized. With ellipsoidal retorts, the two diameters of which were 20 inches and 10 inches respectively, charged with 1½ bushel, and each charge worked off in hours, 61 chaldron 8 bushels of coals yielded 14,000 cubic feet of gas per chaldron, and required for carbonization 19 chaldrons 27 bushels of coals, or 32 per cent. of the quantity carbonized. Mr. Peckston likewise states that five elliptical retorts are capable of carbonizing 45 bushels, or 33 cwt of coals, in 24 hours, but their average work may be taken at 1 chaldron, or 27 cwt. in that time.

Mr. Anderson, of Perth, made a great number of experiments, to determine the comparative quantity of light afforded by candles and coal gas; the size of the candles which he employed, was short sixes. The following are some of the results:—

A 3-jet burner		consumed per hour	2,074	cub. in.	=	6	candles.
An Argand of	5 holes	,,	2,592	,,		8	,,
Ditto	10 ,,	,,	3,798	,,		12	,,
Ditto	14 ,,	,,	5,940	,,		19¼	,,
Ditto	18 ,,	,,	6,840	,,		21	,,

The mean of these results is, that 324 cubic inches of coal gas yield light equal to that of one candle for an hour; but this is the coal gas of Perth, the specific gravity of which, Mr. Anderson says, is 650.

GAS ENGINE. An engine in which the motive force is derived from the alternate expansion and condensation of the liquefiable gases. For the discovery that certain gases may be reduced to the liquid form, and for the suggestion of such gases as prime movers of machinery, we are indebted, (as we have already noticed under the word GAS,) to Sir Humphrey Davy and Mr. Faraday. The important advantages which seemed likely to be realized by this discovery, naturally attracted the attention of engineers and scientific mechanists, and many of the most eminent occupied themselves in endeavouring to devise such arrangements as would render it applicable in practice. The person who pursued the subject with the greatest perseverance was Mr. Brunel, who obtained a patent for an apparatus, in which the liquefiable gases are employed to furnish the moving power, and more especially the carbonic acid gas. This gas may be obtained by decomposing any of the carbonates by the action of the common acids. The mode of obtaining the liquid from the gas is by forming the gas under a gasometer, and condensing it afterwards in another vessel by means of a condensing pump, and continuing the operation until it passes to the liquid state.

The engraving on the next page represents Mr. Brunel's apparatus. This apparatus, as shown at *Fig.* 2, consists of five distinct cylindrical vessels; the two exterior vessels *a* and *b* contain the carbonic acid, reduced to the liquid form, and are called the *receivers;* from these, it passes into the two adjoining vessels *c* and *d*, termed *expansion vessels;* these last having tubes of communication with the working cylinder *e*, the piston therein (shown by dots) is operated upon by the alternate expansion and condensation of the gas giving motion to the rod *f*, and consequently to whatever machinery may be attached thereto. As the working cylinder *e* is of the usual construction, no further description of that part of the apparatus is necessary; and as the two vessels on one side of the cylinder are precisely similar to those on the other, a description of the receiver *a* and the expansion vessel *c* will apply to their counterparts *b* and *d;* the two former (*a* and *c*) are therefore given in a separate *Fig.* 1 on a larger scale, in section, that their construction may be seen, and their operation better understood. The same letters of reference designate the like parts in both figures. The communication of the condensing pump (before mentioned)

with the receiver *a*, is through the orifice *g*, which can be stopped at pleasure by the plug or stop-cock *h*. When the receiver has been charged with the

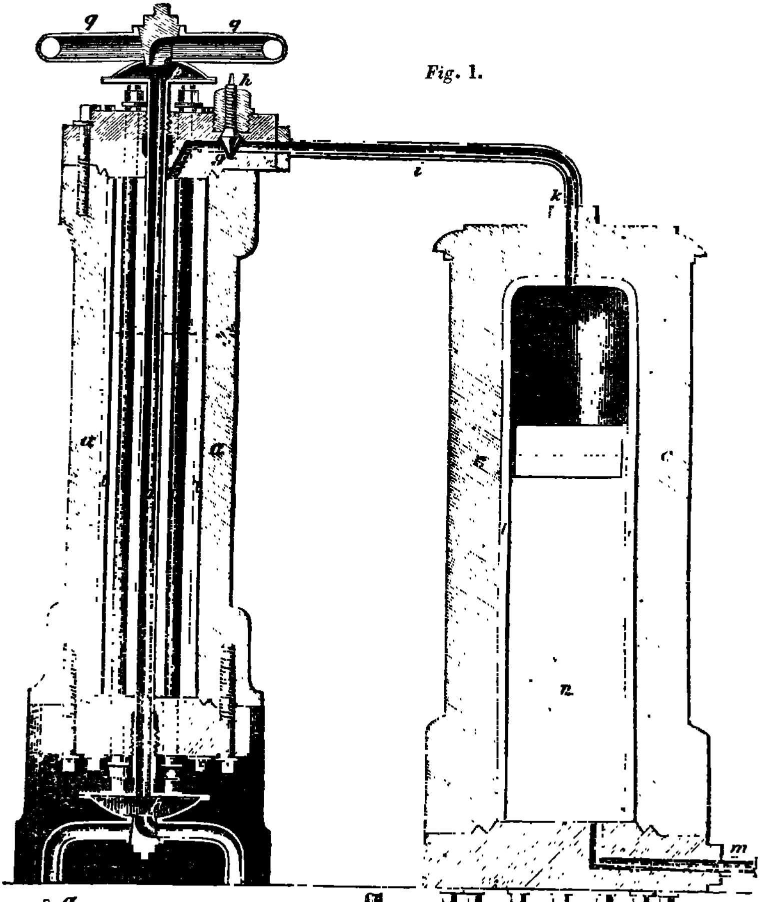


Fig. 1.

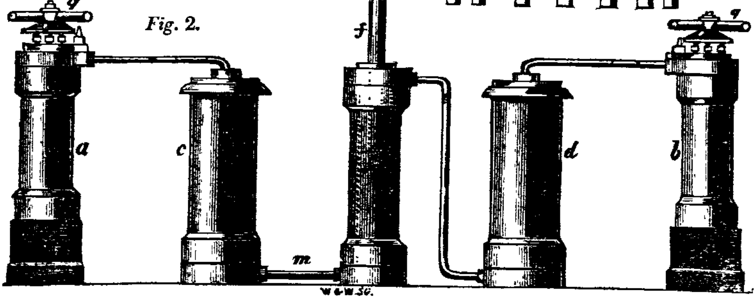


Fig. 2.

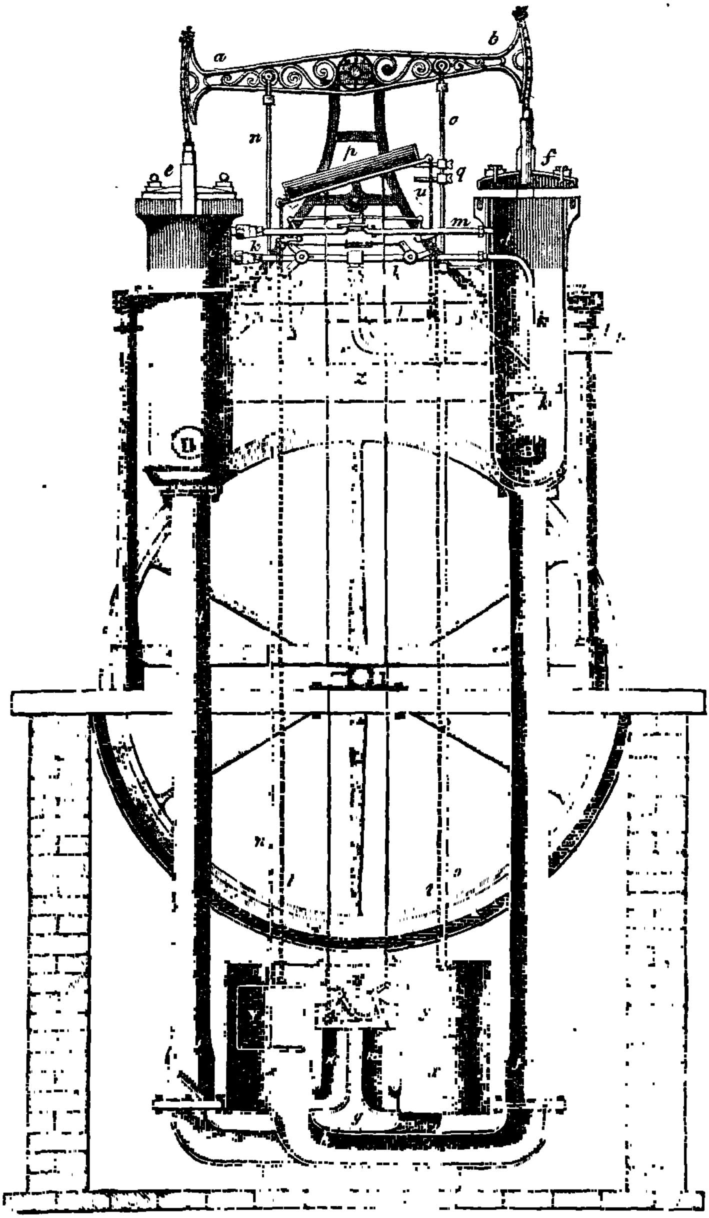
liquid and closed, a pipe *i* is applied to, and connected with the expansion vessel *c* at *k*; *l l* is a lining of wood (mahogany) or other non-conductor of heat, to

prevent the absorption which would otherwise be occasioned by the thick substance of the metal. The expansion vessel is connected through a pipe *m* to the working cylinder *e;* these vessels contain oil, or any other suitable fluid shown at *n*, as a medium between the gas and the piston. The receiver is a strong gun metal vessel, of considerable thickness, in the interior of which are placed several copper tubes, as represented at *o o o;* the joints of these tubes through the top and bottom of the receiver are made perfectly tight by packing. The use of these tubes is to apply alternately heat and cold to the liquid contained in the receiver, without altering very sensibly the temperature of the cylinder. The operation of heating and cooling through the thin tubes *o o o* may be effected with warm water, steam, or any other heating medium; and cold water, or any other cooling medium. For this purpose, the tubes *o o o* are united by a chamber and cock *p p*, by the opening of which, with the pipes *o o*, hot and cold water may be alternately let in and forced through by means of pumps, the cocks being worked in a similar manner to those in steam engines. Now if hot water, say at 120°, be let in through the tubes of the receiver *a*, and cold water at the same time through the receiver *b*, the liquid in the first receiver will operate with a force of about 90 atmospheres, while the liquid in the receiver *b* will only exert a force of 40 or 50 atmospheres. The difference between these two pressures will therefore be the acting power, which through the medium of the oil will operate upon the piston in the working cylinder. It is easy to comprehend that by letting hot water through the receiver *b*, and cold water through the opposite one *a*, a re-action will take place, which will produce in the working cylinder *e* an alternate movement of the piston, applicable by the rod *f* to various mechanical purposes, as may be required. It is to be observed, that the use of the gasometer, and of the forcing pumps, is simply for obtaining the gas, and for charging the receivers with the liquid. When the receiver is once charged, and has been closed with the stop-cock *h*, the gasometer and forcing pumps are to be disconnected from the receiver by unscrewing the pipe *i* at the joint. The same pipe may however be used as the means of connecting the receiver with the expansion vessel; the adoption of two distinct pipes for these purposes is intentionally avoided, as it would become necessary in consequence to have two orifices as well as two stop-cocks. It is obvious that no difficulty exists in connecting the forcing pump with both receivers, as the small pipes used for that purpose may be made to reach either.

Several years have elapsed since the engine just described was patented, but hitherto no machine upon the same principle has been brought into operation; and as the mechanical talents of Mr. Brunel are unquestionable, and as he is known to have devoted much time to bring the invention to perfection, it is probable that the cause of the want of success lies in the principle itself, and that owing to one or both of the causes noticed in Mr. Tredgold's remarks upon the subject, which we have quoted under the word GAS, the liquefiable gases are not so applicable as mechanical agents as the vapour of water or steam. Another difficulty attending such application arises from the very imperfect means we are at present acquainted with of producing the degree of cold necessary for the purpose of condensing the gases; for the present, therefore, there seems little hope of advantageously substituting these gases for steam as a prime mover of machinery.

GAS VACUUM ENGINE. An engine working by the pressure of the atmosphere, a partial vacuum being obtained by the combustion of hydrogen gas in a close vessel. The first person who proposed obtaining power by this means we believe to have been the late Mr. Cecil, of Cambridge, who published some account of his plan, the details of which we do not rightly recollect. In 1824 Mr. S. Brown took out a patent for an engine upon this principle, and at that time the invention excited considerable interest, and was by many looked upon as likely to supersede the steam engine; but although the inventor has since been perseveringly employed, and at a great expense, to bring the machine to perfection, we apprehend he has met with no great success, as the only instances in which we have heard of it being brought into actual use was on one occasion

for raising water on the Surrey Canal, at Croydon, and at another time, for a similar purpose, upon a canal in Oxfordshire; and very contradictory state-

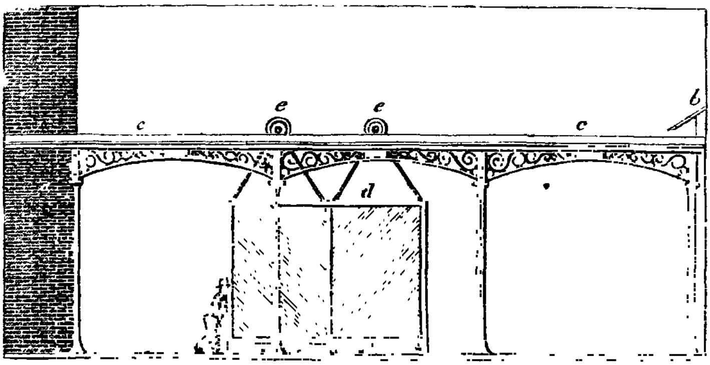


ments prevailed respecting the performance of the engines upon these occasions. The preceding engraving represents the engine as constructed for

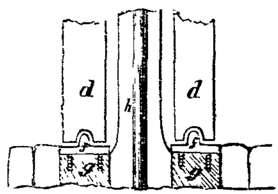
raising water, which, by being led on to a water wheel, may also impart a rotatory motion to machinery; but this latter purpose may be effected by means of pistons working in cylinders. The method of producing the vacuum is as follows:—inflammable gas is introduced along a pipe into an open cylinder or vessel, whilst a flame placed on the outside, but near to the cylinder, is kept constantly burning, and at times comes in contact with the gas therein, and ignites it; the cylinder is then closed air-tight, and the flame is prevented from coming in contact with the gas in the cylinder. The gas continues to flow into the cylinder for a period, and is then stopped off; during that time it acts by *its combustion* on the air within the cylinder, and, at the same time, a part of the rarefied air escapes through one or more valves, and thus a vacuum is effected; the vessel, or cylinder, is kept cool by water. The two cylinders *c* and *d* are the vessels in which the vacuum is to be effected; from these descend the pipes *g i g* and *h j h*, leading into the lower cylinders *x x*, from which the water rises along those pipes to fill the vacuum cylinders alternately. The water thus supplied is discharged through the pipes B into the tank or trough Z, whence it falls upon the overshot water wheel, and by the rotatory motion thus produced, gives power to any machinery which may be connected with it. The water runs from a wheel along a case surrounding the lower half into a reservoir *v*, from which the lower cylinders *x x* are alternately supplied. In order to produce the vacuum, the gas is supplied to the cylinders by means of the pipe *k k k* attached to a gasometer. The gas also passes along the small pipe *l l* (communicating likewise with the gasometer), and being lighted at both ends of that pipe is kept constantly burning for the purpose of igniting the gas within the cylinders. The water in the reservoir *v* passing down one of the pipes *w* into one of the lower cylinders *x*, causes the float *y* in that cylinder to rise, and pushing up the rod *o* raises the end *b* of the beam, which of course draws up with it the cap *f*, and forces down the cap *e* of the other cylinder *c*. The gas being admitted along the pipe *k*, the flame from the pipe *l* is now freely communicated to the gas in the cylinder, through the orifice, by the opening of the sliding valve *s*, which is raised by the arm *r*, lifted by the rod *o* by means of the beam. To produce the intermitting action of each cylinder, some intermediate machinery is put in operation by chains and rods attached to a glass or iron vessel *p*, partly filled with mercury, and turning upon a pivot; each end receives its movements of elevation and depression from the rise and fall of the projecting arms *q*, by the action of the beam above, the mercury being employed for the purpose of regulating the supply of gas into the cylinders, and the movement of the slide in the trough *v*. By the action thus communicated the water from the reservoir flows down the pipe *w* into the vessel *x*, and produces the elevation of the float *y* and of the rod *n*, and raises the cap *e* by the ascent of the beam at *a*. The motion thus caused in this part of the machinery acting upon its duplicate parts on the other side, of course produces by its action a corresponding movement, and the slider in the trough *v*, moved by the action of the mercurial tube *p* being moved from its position, allows the water to fall into the pipe *w*, and as it ascends, suffers the float *y* to descend, and rising into the main cylinder, thus lifts again the beam at *b* and its connexions, and forces down the cap *e* on the top of the other cylinder. After the vacuum is effected in the cylinders, the air must be admitted to allow the water to be discharged, and the caps to be raised; this is accomplished by means of a sliding valve in the air-pipe *m m*, acted upon by chains *t t* attached to floats in the reservoir, and as motion is given to them, the valve is made to slide backwards and forwards, so as to allow of the free admission of atmospheric air. Chains *u u* with suspended weights open the cocks in the pipe *k k*, and produce the alternate flow of the gas, and regulate and modify its supply. In the pipes *g i g* and *h j h*, are docks to prevent the return of the water when the air is admitted into the cylinders.

GATE, in Architecture, a large door leading or giving entrance into an open area, as a field or court-yard, or into a considerable building, as a palace or prison. An excellent method of hanging gates of large dimensions, has been introduced by Mr. H. R. Palmer, which is a useful application of his suspen-

sion railway (see RAILWAY). The following cut represents some sliding or rather rolling gates at each end of the northern avenue of the London Docks, between the warehouses and the basin, forming not only a useful barrier to prevent the intrusion of improper persons during the intervals of cessation of public business, but producing also an ornamental effect. During the hours of business these gates are rolled back against the side walls of the end warehouses, to which they stand close and parallel, occupying no useful room. In opening or shutting them nothing need be moved out of the way, and it is done with great facility and dispatch. Being suspended entirely from above, and not even touching the surface of the ground, it is not subjected to the adventitious obstacles common to other gates. *a a* is intended to represent part of the wall of the ranges of warehouses, and *b* the extremity of the range of sheds on the opposite side of the avenue; *c c* a double railway, extended entirely across the avenue from *a* to *b*, and likewise to the width of a gate beyond on each side; it is supported by slightly curved arches of wrought iron, with ornamental scroll-work between the arches and the double rail, the superstructure resting upon lofty columns of cast-iron. One of three gates *d* (each of which fills up

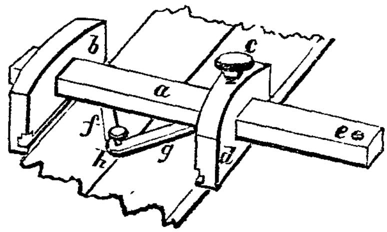


the space between two columns) is shown in the act of being closed, by a man pushing it along; from its large dimensions and great weight (though chiefly composed of wood) this could not be easily effected by the simple force of one man, but being constructed on the principle of Mr. Palmer's patent railway, the friction is reduced to very inconsiderable amount, the whole weight of each gate being entirely suspended by iron rods to the axles of the little wheels which run on the top of the railway, which are kept in their tracks by their peripheries being flanged; the gates do not rest upon or even touch the ground, but are merely guided in their course by means of a projecting edge fixed in their path: this will be easily explained by means of the annexed diagram, which represents a transverse section of these parts. *f f* are two plates of iron, with raised edges in the middle, which are screwed down to open sleepers *g g*, and above these is shown an edge view of the lower ends of the gates, which run on either side of the column *h*. Gates upon the same principle have been put up at the court-yard at the Admiralty, and various other public situations.



GAUGE. An adjustable standard of measure employed in various arts where a number of articles of the same kind are required to be as nearly as possible of the same dimensions. Gauges are various, constructed according to the purposes to which they are to be applied. The cut on the following page represents a gauge contrived by Mr. H. R. Palmer, for the purpose of making a line along the centre of any parallel or tapering

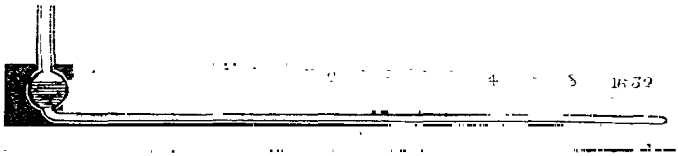
solid. It answers all the purposes of a common carpenter's gauge, whilst it is peculiarly serviceable in other respects, for which the common gauge is wholly inapplicable; in making mortices, and enabling workmen to measure from a centre line, and to work with greater accuracy and facility; and in many other cases it will be found a very convenient instrument. *a* is a square bar of hard wood, having two sliding cheeks *b d* fitted tightly to it; the cheek *b* is fixed fast on one end of the bar, whilst the other slides upon it, but it may be made fast at any required place by means of the thumb screw *c;* at the end *b* a common scribing point is fixed in the bar, and with this and the sliding piece *d* it forms the common gauge used for drawing parallel lines from the edge of any piece of wood work. The addition



made by Mr. Palmer consists of the two brass arms *f* and *g*, of equal lengths, and which are centered in the two sliding cheeks at *a a;* the other ends are jointed together by the screw *h*, which is formed into a sharp conical point beneath to mark the work with. In using this gauge it is evident that the point of the screw *h* will always keep in the centre between the two cheeks *b d.* If the work is not parallel in its width, then the screw *c* must be loosened, and the two cheeks *b d* must be kept pressed towards each other, so as to be in contact with the sides of the work, when the point *g* will traverse along the centre of the piece as correctly as if the sides were parallel, because in all situations it preserves an equal distance from the two cheeks *b* and *d;* these cheeks have grooves made in them to receive the brass arms *f* and *g* when the cheeks are brought into contact.

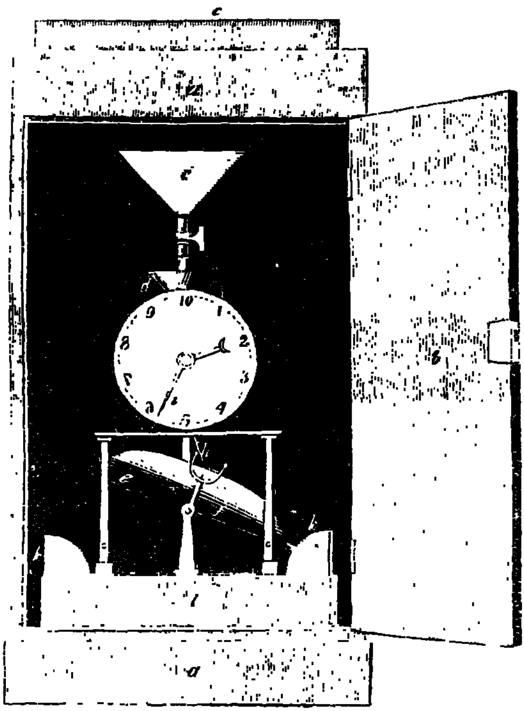
GAUGE, Pressure. An instrument to determine the pressure exerted in hydrostatic or pneumatic machines, as the hydrostatic press, air pump, and steam engine. When the pressure exerted is less than the pressure of the atmosphere, as in the condenser of a steam engine, the gauge is usually termed a barometer, and consists simply of a barometer tube, the lower end of which plunges in a cup containing mercury open to the atmosphere, whilst the upper end communicates with the condenser, and the degree of exhaustion or vacuum, as it is usually termed, is measured by the altitude of the column of mercury in the tube above the surface of the metal in the cup. When the pressure exerted does not exceed two or three times the force of the atmosphere, it may be measured by means of an inverted syphon or bent tube of wrought iron containing a portion of mercury; one leg of the tube communicates with the vessel in which the pressure is exerted, and the other leg is open to the atmosphere, and contains a float by which the rise of the mercury is indicated; but when the pressure is very great, a tube of sufficient length to support the corresponding column of mercury would be extremely inconvenient, and it is usual then to measure the pressure by the compression of a volume of air contained in a glass tube, the upper end of which is sealed, whilst the communication of the air in the tube with the chamber in which the pressure is exerted is intercepted by a quantity of mercury in the lower part of the tube, and the pressure in the chamber acting upon the surface of the mercury exposed to it causes the mercury to rise in the tube, and to compress the air therein into a smaller space, which space will be inversely, as the pressure exerted. The figure on page 617 represents a pressure gauge upon this principle, described in No. LXIII. of the *Philosophical Magazine*, by Mr. H. Russell. The gauge consists of a glass tube, sealed at one end, with a ball blown very near the other, leaving only as much beyond the ball as may be necessary for connecting it with the pipe leading from the vessel containing the condensed steam or gas, or other elastic vapour. This ball, when the tube is filled with air, and subject only to atmospheric pressure, should be about three quarters full of mercury, and the whole capacity need not exceed that of the tube more than as two to one. That the

divisions in the scale may be in geometrical progression, the tube is placed in a horizontal position; this renders the instrument altogether so simple in appearance, that persons totally unacquainted with instruments of this description, may at once be brought to understand its nature, and be able to affirm with confidence the degree of pressure to which it is subject. To determine the degree of pressure at any point, ascertain the distance from the sealed end of the tube, and by that measure divide the length contained between the sealed end and the bulb, the quotient will be the number of atmospheres. Thus in general terms, where T represents the whole tube, P the part into which the column of air is compressed, and A the number of atmospheres, we have



$\frac{T}{P}=A$. Thus, suppose the tube 8 feet long, and the column of air compressed into half that length, then w have $\frac{3}{4}=2$ atmospheres. If this column be again compressed into half its volume, it will be represented by $\frac{3}{2}=4$ atmospheres;—if, again, compressed into half its volume, we have $\frac{3}{1}=8$ atmospheres;—if, again, (8 feet=96 inches) $\frac{96}{6}=16$ atmospheres;—and lastly, $\frac{96}{3}=32$ atmospheres. In the above figure the mercury chamber is blown in the tube itself, so that in this plan we have no joints whatever to make in the instrument; and being placed in a horizontal position at a convenient distance from the floor, all parts of the scale may be examined with equal facility. For the internal diameter of the tube, perhaps one-sixteenth of an inch will be found preferable.

GAUGE, Rain. An instrument for showing the depth of rain or quantity falling on a given surface at any place. These instruments are variously constructed; the one shown in the engraving on the following page is the invention of Mr. Crossley, and is an elegant application of his patent liquid metre. The principal parts of this machine, which are enclosed in a small box *a a* and *b*, are, a small tin vessel or tumbler *e f*, which is divided into two equal parts by a vertical partition, where it is supported by pivots on the upright stem I. The pivots are placed below the centre of gravity of the tumbler, so that when it is tilted (as represented in the engraving), it will remain in that position till the upper half receives such a quantity of water as will overbalance it, when the end *e* will be depressed by the weight of the water, and emptied; the end *f* will, in consequence, be elevated and brought under the spout to receive the water until it becomes sufficiently loaded to preponderate, when it will again take the position in the figure. Attached to this tumbler is a forked projection, that at every change of position, acts on a lever at *h*, and thus communicates motion to a train of wheels, which, by the index and the dial face *i*, is made to register the number of times the divisions of the tumbler have been filled. The rain is received and conveyed into the tumbler by the hopper-shaped vessel *c c*, the mouth of which must be made of an area, having such a relation to the other parts that the index will point out the number of inches of rain falling on that extent of surface; or, in other words, how deep the water would have become had it remained on the surface of the earth during a single shower, a day, a month, or even a year, if required, and this, too, without any attention or care being bestowed upon it—for the apparatus is so simple in construction, that it is not subject to derangement of its parts; and as it registers during the falling of the shower, it requires no estimation to be made of the



quantity of water evaporated between the falling of the rain and the time of observation.

GAUGING.—The art of measuring the capacities of all kinds of vessels. Gauging of course forms a part of mensuration, and is accordingly treated of by most writers on that branch of science; but as casks are seldom of any exact mathematical forms, the rules laid down by such authors must be considered as merely theoretical; and in practice, gauging is performed mechanically, by means of the gauging or diagonal rod, or by the gauging sliding rule. The diagonal or gauging rod is a rod or rule adapted for determining the contents of the casks, by measuring the diagonal only; viz. the diagonal from the bung to the extremity of the opposite stave next the head. It is a square rule, having four sides or faces, and is usually four feet long, and folds together by means of joints. Upon one face of the rule is a scale of inches, for taking the measure of the diagonal; to these are adapted the areas, in gallons, of circles to the corresponding diameters. Upon the opposite face is a scale, expressing the contents of casks, having a corresponding diagonal; and these lines constitute the difference between the diagonal rods and the slide rules. To use the diagonal rods, put the rod in at the bung hole of the cask, until its end touch the opposite stave at the farthest possible distance from the bung-hole, and note the inches and parts cut by the middle of the bung; then draw out the rod, and look for the same inches and parts on the opposite face of it, and on them will be found the contents, in gallons. The sliding rule is similar to the common sliding Gunters, (see GUNTER'S SCALE,) but having certain divisors, or gauge points at different points of the scale, pointed out by small brass pins, which divisors are the number of cubic inches in any particular measure, as malt bushels, or imperial gallons, the casks are gauged approximately as

cylinders, taking a mean diameter, for which purpose they are generally reduced to what is called four varieties; and if the difference between the head and the bung diameters does not exceed six inches, their mean diameters may be found by multiplying the difference of the first by ·68; of the second, by ·62; of the third, by ·55; and of the fourth, by ·5; the respective products of these numbers, added to the head diameter, will make a mean diameter. Having found a mean diameter, the contents are found by setting the length of the cask upon the line marked B, on the brass slider, against the gauge-point, for gallons, on the upper line A, upon the rule, and against the mean diameter upon the lower line D; upon the rule will be found the contents on C upon the slider. On the back of the rule are four other lines, differently marked. The first line is marked D, and is similar to the same line upon the opposite side, and upon this line are set the circular gauge-point for wine, and various other gauge-points; the second line is upon the slider—it is marked C, and is similar to the same line C upon the opposite face; the third and fourth lines on this instrument are two lines of segments, for ullaging the casks, as it is termed, that is, finding the contents of a cask, only partly full. One of these lines is marked S S, for segment standing, and the other S L, for segment lying; these lines are set upon the rule, and are both numbered alike, from 1 to 10, and from 10 to 100. To find the ullage of a lying cask by the line of segments, having the bung diameter, the depth of the liquid in inches, and the contents of the cask, set the bung diameter on C to 100, on the line of segments marked S L, and opposite the depth of liquid on C will be a number on the line of segment, which call the reserved number; then set 100 on A to the contents of the cask upon B, and against the reserve number before found upon A is the contents of the cask upon B. To find the ullage of a cask standing, substitute the length for the bung diameter, and the line S S, for the line S L, and proceed as before.

To facilitate computations in gauging, Mr. W. Gutteridge has invented a series of new units of measure, which has received the approbation of every individual member of the Commission of Weights and Measures. These units of measure are numbered 1, 2, 3, 4, 5, 6, 7, 8, No. 4 being the common decimal foot, which is introduced to complete the series. These units are all decimally subdivided into 100 equal parts, and are the roots of the cubic and superficial measures in which the capacities of vessels, or solid contents of bodies are reckoned, as gallons for liquids, and cubic feet for timber. By this means, no division is necessary in computing contents or capacities, for the area expressed in Mr. Gutteridge's system of notation multiplied by the depth gives the contents; whereas, when the dimensions are taken in inches, after multiplying the area by the depth, it is necessary to divide the product by the number of inches in a gallon or a foot to find the contents. Mr. Gutteridge's units of measure, with their data, are as follows:

For imperial Gallons.

No. 1.	$\sqrt[3]{277{\cdot}274}$	= 6·52083	Inches.	= 1	Units.
2.	$\sqrt[3]{277{\cdot}274} \times \sqrt{\cdot\frac{1}{7854}}$.	= 7·35784	„	= 1	„
3.	$\sqrt[3]{277\cdot\frac{274}{7854}}$	= 7·0676	„	= 1	„
4.	is the common foot.				

For Feet.

No. 5.	$\sqrt{\cdot\frac{1}{7854}}$	= 1·12836	Feet.	= 1	Units
6.	$\sqrt[3]{\cdot\frac{1}{7854}}$	= 1.08383	„	= 1	„
7.	$\cdot\frac{1}{7854}$	= 1.2732	„	= 1	„
8.	$\sqrt[3]{144}$	= 5·2415	Inches.	= 1	„

In connexion with the subject of gauging, we may notice a singular circumstance related by Mr. Gutteridge. He had been called in to gauge a new vat for Messrs. Booth & Co. distillers, and his own system was employed as affording

greater accuracy than the inch method in common use. After the dimensions had been taken, a glass tube was fixed on the outside of the vat, for reading off the quantities within, as a means of comparison with the interior dip. That no difference might arise from the effect of capillary attraction, the tube was made of more than an inch bore, and was fixed perpendicularly, with a graduated scale placed closely, so that the zero of the scale coincided with the top of the ungula, which exactly covered the bottom, without producing any sensible depth of wet at the dipping place, from which it was inferred that the interior *dip*, and the exterior indications of *level* would be always the same; and upon putting in several determined quantities, those quantities were indicated by the tube exactly; but a difference was afterwards perceived between the interior dip and the exterior level, and the greater the quantity, the greater the difference. The experiment was frequently repeated, with every precaution to guard against error, one source of which was the difference of temperature in the vat and in the tube, amounting in one instance to $2\frac{1}{2}$ degrees, which would cause a difference of about ·085 of an inch, (the spirit being 41·6 per cent. over proof,) but to save computations of this sort, the time chosen for the principal experiment was when the temperature was alike. With 1400 gallons in the vat, the difference was about $\frac{6}{10}$ of an inch; 2200 gallons more were then pumped in, and the difference increased to $\frac{98}{100}$ of an inch, and on adding 700 gallons more, the difference amounted to $1\frac{1}{10}$ inch. It appearing highly improbable that the timbers could compress so much more under the dipping place than under where the tube was fixed, a level of the two surfaces was taken, and, extraordinary as the fact may appear, there was a difference found in the levels, of $\frac{4}{10}$ of an inch, the liquid being that much higher in the vat than the tube. This difference Mr. Gutteridge imputes to a difference in the specific gravity of the spirit within the vat, and that within the tube, and upon assaying them the former was found to be nearly 5 per cent. stronger than the latter. This variation must have been caused by a greater evaporation on the tube, and it shows that with spirits of such great strength, evaporation is very rapid, and cannot be too carefully guarded against. The remaining difference between the dip and the level in the tube Mr. Gutteridge supposes to have arisen from a compression of the timbers under the dipping place.

The following diagrams of the vat, tube, and timbers, will render the subject more intelligible. *Fig.* 1 represents a section of the vat, *a b* being the tube fixed into a metal pipe *b c*, with a cock at *c d*, the level of the spirit in the vat; *f* the level in the tube, and *h i* the dipping place. *Fig.* 2. shows the supports of the vat; B the back, and F the front, of which the seven similar parts *a a* are the immediate rests, each four inches square; *b b b* the three timbers upon which the former rest, $10\frac{1}{2}$ inches deep, and $12\frac{1}{2}$ broad; *c c* the two sleepers upon which the beams are laid. The places *d d d d* are supported upon four upright posts, and under *k* was placed another support; *l* the orifice for the tube pipe, and *o* the dipping place.

Fig. 1.

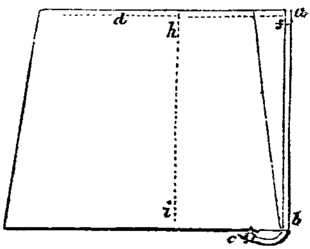
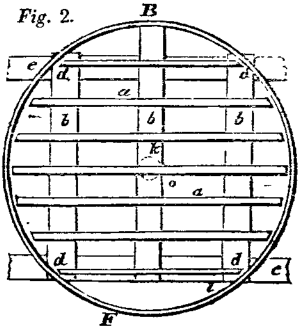


Fig. 2.



GAUZE. A thin, transparent kind of stuff, woven sometimes of silk, and sometimes of thread. To warp the silk for the making of gauze, a peculiar kind of mill is used, upon which the silk is wound: it is a wooden machine, about six feet high, having an axis perpendicularly placed in the middle thereof, with six large wings, on which the silk is wound from off the bobbins by the axis turning round. When all the silk is on the mill, another instrument is used to wind it off upon two beams; this done, the silk is passed through as many little beads as there are threads of silk; and thus rolled on to another beam to supply the loom. The gauze loom is much like that of the common weaver's, though it has several appendages peculiar to itself. Some gauzes are wrought into figures and flowers of gold and silver, upon a silk ground.

GEARING. A train of toothed wheels, for transmitting motions in machinery. There are two sorts of gearing in common; viz. spur gear and beveled gear. In the former, the teeth are arranged round either the concave or convex surface of a cylindrical wheel in the direction of radii from the centre of the wheel, and are of equal depth throughout. In beveled gear, the teeth are placed upon the exterior periphery of a conical wheel in a direction converging to the apex of the cone, and the depth of the tooth gradually diminishes from the base. For the rules for setting out these wheels, and for the best form of teeth, we refer to the article MILL WORK, and shall, in this place, only notice a new system of gearing, invented simultaneously by Mr. Dyer, in America, and by Messrs. M'Dougall, of Ferry Bridge, in Yorkshire, and communicated by the former gentleman to Mr. H. Burnett, who took out a patent for the same. The object of this invention is to obtain a great difference in the relative velocities of the wheel and pinion, by a construction which in some respects resembles what is called a *worm wheel*, or a wheel driven by an endless screw, but is at the same time free from the objections attending the ordinary arrangement of the wheel and endless screw. The common application of the wheel and endless screw is in the direction of a tangent line, (or very nearly so) to the wheel to which it is applied, and the force exerted upon it or by it, is constantly in a direction coincident with its longitudinal axis, and never in that of its radius, whilst a rubbing action takes place between the threads of the screw and the teeth of the wheel, thus producing excessive friction, not only at the point of contact, but also against the pivot or resisting point of the screw. In the patent gearing, the axis of the screw, or spiral pinion, is not a tangent to the wheel, but lies in the same plane as the axis of the wheel in ordinary gear, whether it be spur gear or beveled gear. The consequence of this arrangement is, that the power of the screw or spiral is exerted in the direction of its radius; consequently, it can be driven by the wheel with the same facility with which the wheel drives it (difference of leverage, according to their respective radii, excepted), which is not the case with the ordinary wheel and screw. Another advantage is, that there being but one point of bearing in action at once, and that uniformly on the line of centres, and that action passing uniformly over equal spaces, in equal times, and in the same direction; the action which takes place between the wheel and the spiral pinion is not a sliding, but a perfect rolling action, whereby nearly the whole of the friction which would otherwise occur, is avoided. One valuable property of this invention is, that any required strength may be given to the arbor, without affecting its power or velocity; this will be rendered evident by an inspection of *Fig.* 3 on the following page, in which the external lines *e e* and *f f* represent the sections of two arbors of very different sizes, and consequently strengths, while their mechanical action is precisely similar, for it will be seen that, notwithstanding the difference of magnitude in the two sections, they have but one common pitch-line, marked *i i* in both figures, so that both can work in the same wheel, and their power and velocity must be equal. *Fig.* 4 represents the arbor or pinion engaged with the tooth of a wheel. Another most important advantage belonging to this system of gearing, is the simplicity which may be thereby introduced into machinery, and the consequent diminution of friction; for since each tooth of the wheel will be equivalent to an entire revolution of the arbor, a great saving may be effected; thus, for

instance, if a common wheel has 100 teeth, and works into a pinion of ten leaves, the same power or velocity may be obtained by the new mode of gearing, by using a wheel of only ten teeth, working into one spiral groove upon the arbor; as an example of which *Fig.* 1 is a side, and *Fig.* 2 a front elevation

Fig. 2.

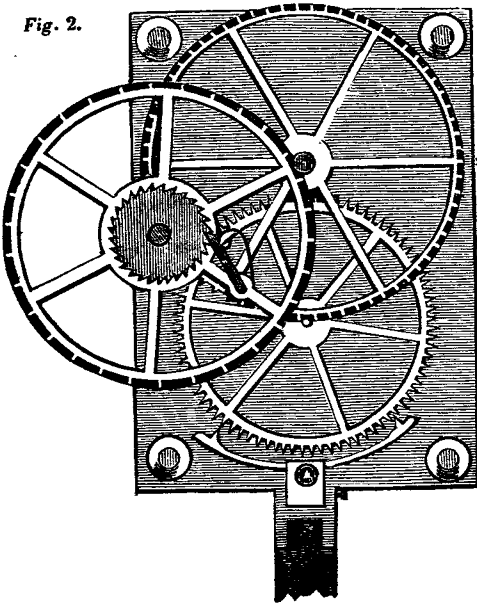


Fig. 1.

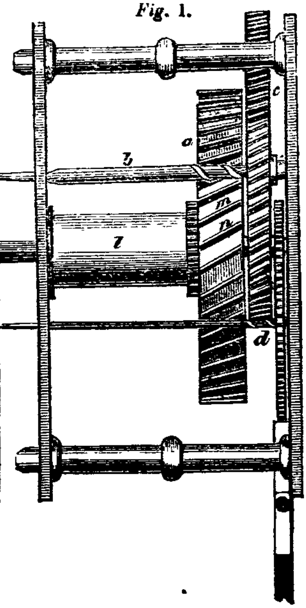


Fig. 4.

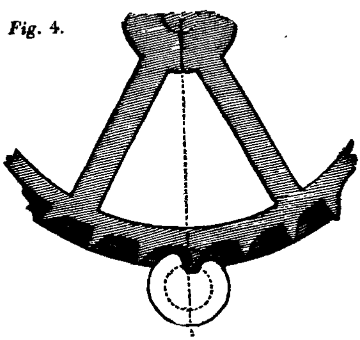
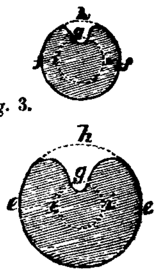


Fig. 3.



of a regulator clock, which is capable of showing hours, minutes, and seconds, and will go for a whole year with once winding up, by a weight of only a few pounds. The curve of the spiral groove on the arbor may be found by covering the face of the wheel with a strip of thin paper, and marking the bevel of one tooth upon it, when the extension of that tooth may be cut off and wrapped round the arbor, which will give the form of the spiral, which may be marked and cut; but this is only a proximate method, and as the action of the improved gearing, like that of all other gearings, depends mainly upon the perfect working of the teeth and grooves, it is better to cut the groove on the arbor, in a regular and proper machine for cutting spirals and screws.

GELATIN. An animal substance soluble in hot water, capable of assuming a well known elastic or tremulous consistence by cooling, when the water is not too abundant, and liquefiable again by increasing its temperature. This last property distinguishes it from albumen, which becomes consistent by heat. It is precipitated in an insoluble form by tannin, and it is this action of tannin on gelatin which is the foundation of the art of tanning leather.

GEMS. This word is used to denote such stones as are considered by mankind as precious. These are, the diamond, the ruby, sapphire, topaz, chrysolite, beryl, emerald, hyacinth, amethyst, garnet, tourmalin, opal; and to these may be added, rock crystal, the finer flints of pebbles, cat's eye, hydrophanes, chalcedony, moon-stone, onyx, cornelian, sardonyx, agates, and Labrador stone, for which, consult the several articles respectively.

GEOMETRY. One of the most important of the mathematical sciences; as it relates to the form, extension, and magnitude of bodies, and is consequently the foundation of Mensuration. The most generally useful portion of this science has been selected for our pages, which we here annex under the usual distinctive appellation of *Practical Geometry.*

Definitions.—A *point* is that which hath position, but not magnitude.

A *line* hath length, but not breadth or thickness, and may therefore be conceived to be generated by the motion of a point.

A *right line* is what is commonly called a straight line, or that tends every where the same way.

A *curve* is a line which continually changes its direction between its extreme points.

Parallel lines are such as are equally distant from each other, and which, if prolonged ever so far, would never meet: such are the lines A B and C D, *Fig.* 1.

An *angle* is the space or corner between two lines meeting in a point, as A B C, B denoting the vertex, or angular point.

A *right angle* is represented when one line stands upon another, so as not to lean more upon one side than upon the other, as in the angles A B C in *Fig.* 3; all right angles are equal to each other, being all equal to 90°; and the line A B is said to be perpendicular to C D.

Fig. 1.

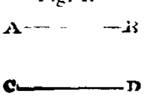


Fig. 2.

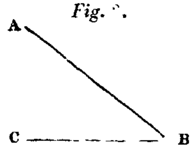
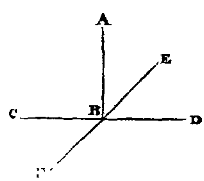


Fig. 3.



Beginners are very apt to confound the terms *perpendicular*, and *plumb* or *vertical line.* A line is vertical when it is at right angles to the plane of the horizon, or level surface of the earth, or to the surface of water, which is always level. The sides of a house are vertical. But a line may be perpendicular to another, whether it stand upright or incline to the ground, or even if it lie flat upon it, provided only that it make the two angles formed by meeting with the other line equal to each other; as, for instance, if the angles A B C and A B D be equal, the line A B is perpendicular to C D, whatever may be its position in other respects.

When one line B E, *Fig.* 3, stands upon another, C D, so as to incline, the angle E B C, which is greater than a right-angle, is called an *obtuse* angle; and that which is less than a right angle, is called an *acute* angle, as the angle E B D.

Two angles which have one leg in common, as the angles A B C and A B E, are called *contiguous* angles, or *adjoining* angles; those which are produced by the crossing of two lines, as the angles E B D and C B F, formed by C D and E F crossing each other, are called *opposite* or *vertical* angles.

A *figure* is a bounded space, and is either a *surface* or a *solid*.

A *superficies*, or *surface*, has length and breadth only. The extremities of a superficies are lines.

A surface may be bounded either by straight lines, curved lines, or both these. Every surface, bounded by straight lines only, is called a *polygon*. If the sides be all equal, it is called a *regular polygon*. If they be unequal, it is called an *irregular polygon*. Every polygon, whether equal or unequal, has the same number of sides as angles, and they are denominated sometimes according to the number of sides, and sometimes from the number of angles they contain. Thus, a figure of three sides is called a triangle, and a figure of four sides, a *quadrangle*.

A *pentagon* is a polygon of five sides.

A *hexagon* has six sides.

A *heptagon* has seven sides.

An *octagon* has eight sides.

A *nonagon*, nine sides.

A *decagon*, ten sides.

An *undecagon*, eleven sides.

A *duodecagon*, twelve sides.

When they have a greater number of sides, it is usual to call them polygons of 13 sides, 14 sides, and so on.

Triangles are of different kinds, according to the length of their sides.

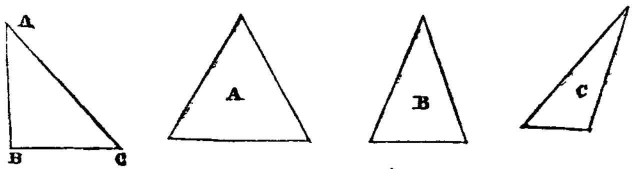
A *right-angled triangle* is that which has one right angle, as A B C, *Fig*. 1.

An *acute-angled triangle*, is a triangle which has all its sides acute, as *Figs*. A and B.

An *obtuse-angled triangle*, is a triangle having one obtuse angle, as *Fig*. C.

An *equilateral triangle*, is a triangle having all its sides equal, as *Fig*. A.

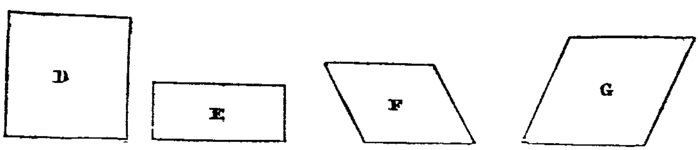
Fig. 1.



An *isoceles triangle*, is a triangle having two equal sides, as *Fig*. B.

A *scalene triangle*, is a triangle having no two of its sides equal, as *Fig*. C.

Quadrangles or *quadrilateral* figures are of various denominations, as their sides are equal or unequal, or as all their angles are right angles or not.



Every four-sided figure, whose opposite sides are parallel, is called a *parallelogram*. Provided that the sides opposite to each other be parallel, it is immaterial whether the angles be right or not. *Figs*. D E F and G, are all parallelograms.

When the angles of a parallelogram are all right angles, it is called a *rectangular parallelogram*, or a *rectangle*, as *Figs*. E and D.

A rectangle may have all its sides equal, or only the opposite sides equal. When all its sides are equal, it is called a *square*, as *Fig*. D.

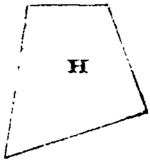
When the opposite sides are parallel, and all the sides equal to each other, but the angles not right angles, the parallelogram is called a *rhombus*, as *Fig*. G.

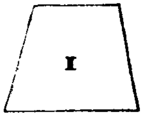
A parallelogram, having all its angles oblique, and only its opposite equal, is called a *rhomboid*, as *Fig* F.

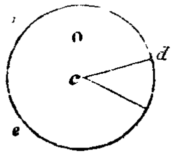
When a quadrilateral, or four-sided figure, has none of its sides parallel, it is called a *trapezium*, as *Fig.* H, consequently, every quadrangle or quadrilateral, which is not a parallelogram, is a trapezium.

A *trapeziod* has only one pair of its sides parallel, as *Fig.* I.

A *circle* is a plane figure, bounded by a curve line returning into itself, called its *circumference*, *b d e*, *Fig.* O, every where equally distant from a point within the circle, which is called the centre, *c*.







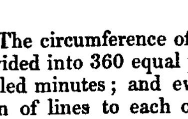
The *radius* of a circle is a straight line drawn from the centre to the circumference, as *c d*, *Fig.* O. The radius is the opening of the compass when a circle is described; and consequently, all the radii of a circle must be equal to each other.

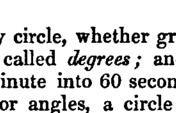
A *diameter* of a circle is a straight line drawn from one side of the circumference to the other through the centre, as *a b*, *Fig.* P. Every diameter divides the circle into two equal parts.

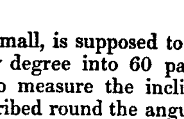
A *segment* of a circle is a part of a circle cut off by a straight line drawn across it. This straight line *f h*, *Fig.* R, is called the *chord.* A segment may be either equal to, greater, or less, than a *semi-circle*, which is a segment formed by the diameter of the circle, and is equal to half the circle, as in *Fig.* P.

A *tangent* is a straight line, drawn so as just to touch a circle without cutting it, as *d e*, *Fig.* T. The point where it touches the circle, is called the *point of contact;* and a tangent cannot touch a circle in more points than one.

A *sector* of a circle is a space comprehended between two radii and an arc, as *a c b*, *Fig.* T.







The circumference of every circle, whether great or small, is supposed to be divided into 360 equal parts, called *degrees;* and every degree into 60 parts, called minutes; and every minute into 60 seconds. To measure the inclination of lines to each other, or angles, a circle is described round the angular point, as a centre, as *a b*, *Fig.* T, and according to the number of degrees, minutes, and seconds, cut off by the sides of the angle, so many degrees, seconds, and minutes, it is said to contain. Degrees are marked by °, minutes by ′, and seconds by ″; thus an angle of 48 degrees, 15 minutes, and 7 seconds is written in this manner, 48° 15′ 7″.

Problem I.—*To divide a given line* A B *into two equal parts.*

From the end of the line A and B, *Fig.* 1, as centres, and with any opening of the compasses greater than half A B, describe arches, cutting each other in *c* and *d*. Draw the line *c d*; and the point E, where it cuts A B, will be the

middle required. This is often effected by practical men assuming a distance as half, and setting off from each end of the line, and then bisecting the space between the distances set off by the eye.

Problem II.—*To raise a perpendicular to a given line* A B, *from a point given at* C.

Case 1. When the given point is near the middle of the line, on each side of the point C, *Fig.* 2. Take any two equal distances, C *d* and C *e*; from *d* and *e*, with any radius or opening of the compasses greater than C *d* or C *e*, describe two arcs cutting each other in *f*. Lastly, through the points *f*, C, draw the line *f g*, and it will be the perpendicular required.

Case 2. When the point is at, or near the end of the line, take any point *d*, *Fig.* 3, on the side of the line on which the perpendicular is to be drawn, and with the radius or distance *d c*, describe the arc *e c f*, cutting *e* B in *e* and *c*. Through the centre *d*, and the point *e*, draw the line *e d f*, cutting the arc *e c f* in *f*. Through the points *f c*, draw the line *f c*, and it will be the perpendicular required.

Problem III.—*From a given point f, to let fall a perpendicular upon a given line* A B.

Case 1. From the point *f Fig.* 2, with any radius, describe the arc *d e*, cutting A B in *e* and *d*. From the points *e d*, with the same or any other radius, describe two arcs, cutting each other in *g*. Through the points *f* and *g* draw the line *f g*, and *f* C will be the perpendicular required.

Case 2. If the point be nearly over the end of the line, from it as at *f*, *Fig.* 3, draw a line *e f* obliquely to the other end; bisect *e f*, in *d*, and with the radius *d e* draw the arc *f c e*, cutting the given line at *c*, to which the required perpendicular from *f* is to be drawn.

Fig. 1.

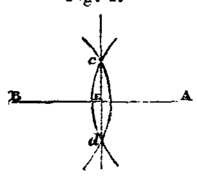


Fig. 2.

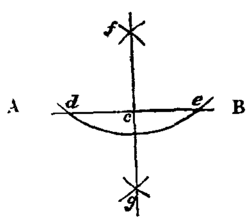
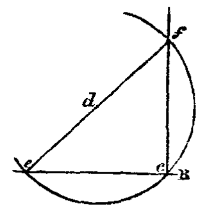


Fig. 3.



Problem IV.—*To make an angle equal to another angle which is given, as a* B *b*.

From the point B, *Fig.* 4 with any radius, describe the arc *a b*, cutting the legs B *a*, B *b*, in the points *a* and *b*. Draw the line D *b*, and from the point D, with the same radius as before, describe the arc *b f*, cutting D *b* in *b*. Take the distance *b a*, and apply it to the arc *b f*, from *b* to *f*. Lastly, through the points D *f*, draw the line D *f*, and the angle *b* D *f* will be equal to the angle *b* B *a*, as was required.

Problem V.—*To divide a given angle,* A B C, *into two equal parts or angles.*

From the point B, *Fig.* 5, with any radius, describe the arc A C. From A and C, with the same, or any other radius, describe arcs cutting each other in *d*. Draw the line B *d*, and it will bisect the angle A B C as was required.

Problem VI.—*To lay down an angle of any number of degrees.*

There are various methods of doing this. One is by the use of an instrument called a *protractor*, with a semicircle of brass, having its circumference divided

into degrees; similar to *Fig.* 6. Let A B be a given line, and let it be required to draw from the angular point A a line making, with A B, any number of degrees, suppose 40. Lay the straight side of the protractor along the line A B, and count 40° from the end B of the semicircle; at C, which is 40° from B, mark; then, removing the protractor, draw the line A C, which makes, with A B, the angle required. Or, it may be done by a divided line, usually drawn upon scales, called a *line of chords.* Take 60° from the line of chords, in the compasses, and setting one at the angular point B, Prob. IV., with that opening as a radius, describe an arch, as *a b:* then take the number of degrees of which you intend the angle to be, and set it from *b* to *a*, then is *a* B *b* the angle required.

Fig. 4.

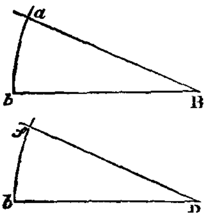


Fig. 5.

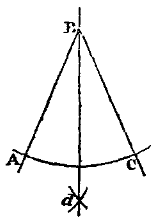


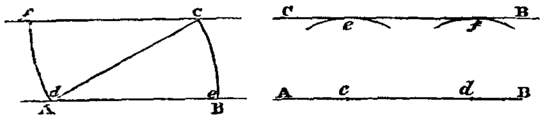
Fig. 6.

Problem VII.—*Through a given point* C, *to draw a line parallel to a given line* A B.

Case 1. Take any point *d,* in A B, *Fig.* 7, upon *d* and C, with the distance C *d,* describe two arcs, *e* C, and *d f,* cutting the line A B, in *e* and *d.* Make *d f* equal to *e* C; through C and *f* draw C *f,* and it will be the line required.

Case 2. When the parallel is to be at a given distance from A B. From any two points *c* and *d,* in the line A B, with a radius equal to the given d s-tance, describe the arcs *e* and *f:* draw the line C B to touch those arcs without cutting them, and it will be parallel to A B, as was required.

Fig. 7.



Problem VIII.—*To divide a given line* A B, *into any proposed number of equal parts.*

From A, *Fig.* 8, one end of the line, draw A C, making any angle with A B; and from B, the other end, draw B 9 parallel to A C, making the angle A B 9 equal to B A C. In each of these lines A C, B 9, beginning at A and B, set off as many equal parts, of any length, as A B is to be divided into. Join the points C 5; 4, 6; 3, 7; and A B will be divided as required.

Problem IX.—*To find the centre of a given circle.*

Draw any chord A B, *Fig.* 9, and bisect it with the perpendicular C D. Bisect C D with the diameter E F, and the intersection O will be the centre required. Or the intersection of two lines drawn perpendicularly through two of its chords, will be the centre of a circle.

Problem X.—*To draw a tangent to a given circle that shall pass through a given point,* A.

From the centre O, *Fig.* 10, draw the radius O A. Through the point A, draw D F perpendicular to O A, and it will be the tangent required.

Fig. 8.

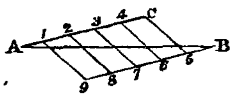


Fig. 9.

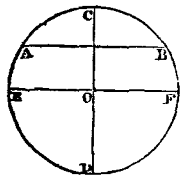
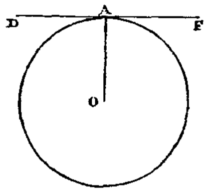


Fig. 10.



Problem XI.—*To draw a tangent to a circle, or any segment of a circle* A B C *through a given point* B, *without making use of the centre of the circle.*

Take any two equal divisions upon the circle, *Fig.* 11, from the given point B towards *d* and *e*, and draw the chord *e* B. Upon B, as a centre, with the distance B *d*, describe the arc *f d g*, cutting the chord *e* B in *f*. Make *d g* equal to *d f;* through *g* draw *g* B, and it will be the tangent required.

Problem XII.—*Given three points,* A, B, C, *not in a straight line, to describe a circle that shall pass through them.*

Bisect the lines A B, B C, *Fig.* 12, by the perpendiculars *a b*, *b a*, meeting at *d*. Upon *d*, with the distance *d* A, *d* B, or *d* C, describe A B C, and it will be the required circle.

Fig. 11.

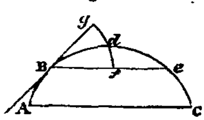
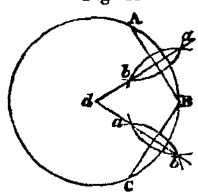


Fig. 12.



Problem XIII.—*To describe the segment of a circle to any length* A B, *and height* C D.

Bisect A B, *Fig.* 13, by the perpendicular D *g*, cutting A B in *c*. From *c* make *c* D, on the perpendicular, equal to C D. Draw A D, and bisect it by a perpendicular *e f*, cutting D *g* in *g*. Upon *g* the centre, describe A D B, and it will be the required segment.

Fig. 13.

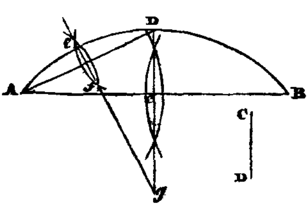
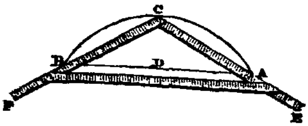


Fig. 14.



Problem XIV.—*To describe the segment of a circle by means of two rules, to any length* A B, *and perpendicular height* C D, *in the middle of* A B, *without making use of the centre.*

Place the rules to the height at C, *Fig.* 14; bring the edges close to A and B; fix them together at C, and put another piece across them to keep them fast. Put in pins at A and B, then move the rulers round these pins, holding a pencil at the angular point C, which will describe the segment.

Problem XV.—*In any given triangle to inscribe a circle.*

Bisect any two angles A and C, *Fig.* 15. with the lines A D and D C. From D, the point of intersection, let fall the perpendicular D E; it will be the radius of the circle required.

Problem XVI.—*In a given square, to describe a regular octagon.*

Draw the diagonals A B and C D, *Fig.* 16, intersecting at *e*. Upon the points A, B, C, D, as centres, with a radius *e* C, describe the arcs *h e l, k e n, m e g, f e i.* Join *f n, m h, k i, l g,* and it will be the required octagon.

Problem XVII.—*In a given circle, to describe any regular polygon.*

Divide the circumference into as many parts as there are sides in the polygon to be drawn, and join the points of division. Or divide 360° by the given number of sides, and set off from the radius of the circle, an angle equal to the quotient, and its chord will be one side of the polygon, *Fig.* 17.

Fig. 15.

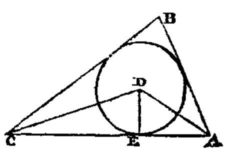


Fig. 16.

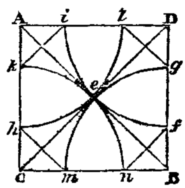
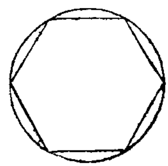


Fig. 17.



Problem XVIII.—*Upon a given straight line,* A B, *to form a polygon of any number of sides.*

Produce the side A B to P, *Fig.* 18, and on A P from the centre B describe a semicircle A C P; divide the semicircumference A C P into as many equal parts as the number of sides intended; through the second division, from P, draw the line B C; bisect A B and P C by perpendiculars cutting each other in S; from S with the radius A S, B S, or C S, describe a circle A B C D E, then carry the side A B or B C round the remaining part of the arc, which will be found to contain the remaining sides of the number required. *Fig.* 18 is an example of a pentagon; we shall give in *Fig.* 19 an example of a hexagon, as in this figure we need not proceed by the general method: we have only to make a radius of the given side A B, and take the points A and B as centres; form the arcs A G and B G, and strike a circle with the radius G A or G B, which will contain the six sides.

Fig. 18.

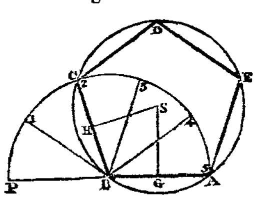
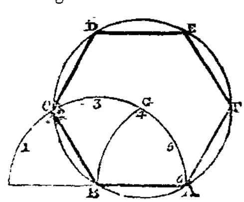


Fig. 19.



Problem XIX.—*Upon a given line A B, to construct an equilateral triangle.*

Upon the points A and B, *Fig.* 20, with a radius equal to A B, describe arches cutting each other at C. Draw A C and B C, and A B C will be the triangle required.

Problem XX.—*To make a triangle, whose sides shall be equal to three given lines D E F, any two of them being greater than the third.*

Draw A B, *Fig.* 21, equal to the line D. Upon A, with the radius F, describe an arc C D. Upon B, with the radius E, describe another arc intersecting the former at C. Draw A C and C B, and A B C will be the triangle required.

Fig. 20.

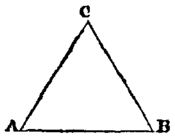
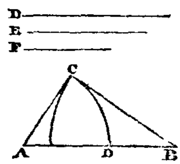


Fig. 21.



Problem XXI.—*To make a figure equal and similar to a given irregular figure,* A B C D.

Divide the given figure as A B C D, *Fig.* 22, into two or more triangles, by the diagonal D B. Make E F equal to A B; upon E F construct the triangle E F H, whose sides shall be respectively equal to those of the triangle A B D, by the last problem. Upon H F, which is equal to D B, construct the triangle H F G, whose sides are respectively equal to D B C, then E F G H will be the figure required.

A figure having more than four sides must necessarily be divided into more than two triangles.

Problem XXII.—*To make a square equal to two given squares.*

Make the sides D E and D F, *Fig* 23, of the two given squares A and B, on opposite sides of the same straight lines, they will form the sides of a right-angled triangle F D E; draw the hypothenuse F E; on it describe the square E F G H, and it will be the square required.

Fig. 22.

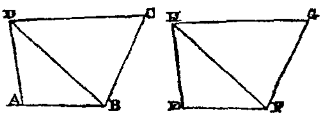
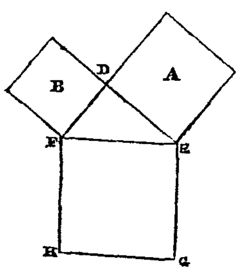


Fig. 23.



Problem XXIII.—*Two right lines* A B, C D, *being given, to find a third proportional.*

Make an angle H E I, *Fig.* 24, at pleasure; from E make E F equal to A B, and E G equal to C D: join F G. Take E I equal to E F, and draw H I parallel to F G; then E H will be the third proportional required; that is, E F: E G : : E H : E I, or A B : C D : : C D : E I.

Problem XXIV.—*Three lines being given, to find a fourth proportional.*

Draw G H and G I, *Fig.* 25, making any angle H G I; take G H equal to A B, G I equal to C D, and draw H I. Make G K equal to E F; draw K L, through K, parallel to H I; then G L will be the fourth proportional required, that is G H : G I : : G K : G L, or A B: C D : : E F : G L.

Problem XXV.—*To divide a given line* A B, *in the same proportion as another* C D, *is divided.*

Make any angle K H I, *Fig.* 26, and make H I equal to A B; then apply the several divisions of C D, from H to K, and join K I. Draw, parallel to I K, the lines *e*, *f*, *g*, *h*, *i*, *k*, *l*, by which the line H I will be divided as was required.

Fig. 24.

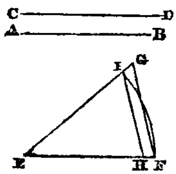


Fig. 25.

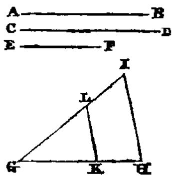
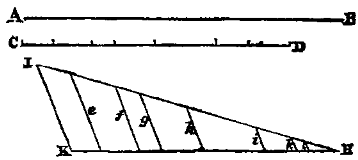


Fig. 26.



Problem XXVI.—*Between two given lines* A B *and* C D, *to find a mean proportional.*

Draw the right line E G, *Fig.* 27, in which make E F equal to A B, and F G equal to C D. Bisect E G in H, and with H E or H G, as radius, describe the semicircle E I G. From F draw F I perpendicular to E G, cutting the circle in I; and I F will be the mean proportional required.

Problem XXVII.—*To describe an ellipsis.*

If two pins be fixed at the points E and F, *Fig.* 28, a string being put about them, and the ends tied together at C; the point C being moved round, keeping the string stretched, will describe an ellipsis.

The points E and F, where the pins were fixed, are called the *foci.*

The line A B passing through the foci, is called the *transverse axis.*

The point G bisecting the transverse axis, is the *centre* of the ellipsis.

The line C D crossing this centre at right angles to the transverse axis, is the *conjugate axis.*

The *latus rectum* is a right line passing through the focus at F, at right angles to the transverse axis terminated by the curve: this is also called the *parameter.*

A *diameter* is any line passing through the centre, and terminated by the curve.

A *conjugate diameter* to another diameter, is a line drawn through the centre, parallel to a tangent, at the extreme of the other diameter, and terminated by the curve.

A *double ordinate* is a line drawn through any diameter parallel to a tangent, at the extreme of that diameter terminated by the curve.

Fig. 27.

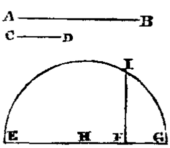
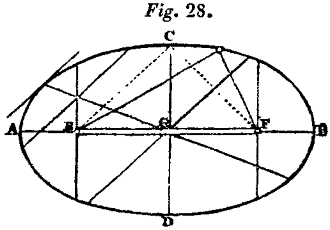


Fig. 28.



PROBLEM XXVIII.—*The transverse axis* A B, *and conjugate axis* C D *of any ellipsis, being given, to find the two foci, and from thence to describe the ellipsis.*

Take the semi-transverse, A E, or E B, *Fig.* 29, and from C as a centre, describe an arc, cutting A B at F and G, which are the foci. Fix pins in these points; a string being stretched about the points, F, C, G, the ellipsis is described as above.

PROBLEM XXIX.—*The same being given, to describe an ellipsis by a trammel.*

The trammel, *Fig.* 30, is an instrument consisting of two rulers fixed at right angles to each other, with a groove in each. A rod, with two movable nuts, works in this groove, and, by means of a pencil fixed in the end of the rod, describes the curve. The operation is as follows:—Let the distance of the first pin at B, from the pencil at A, be equal to half the shortest axis, and the distance of the second pin at C, from A, to half the longest axis; the pins being put in the grooves, move the pencil at A, which will describe the ellipsis.

Fig. 29.

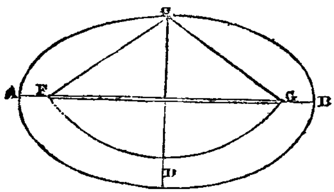
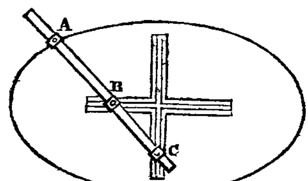


Fig. 30.



PROBLEM XXX.—*To describe an ellipsis similar to a given one* A D B C, *to any given length* I K, *or to a given width* M L.

Let A B and C D, *Fig.* 31, be the two axes of the given ellipsis. Through the points of contact A, D, B, C, complete the rectangle G E H F; draw the diagonals E F and G H: they will pass through the centre at R. Through I and K draw P N and O Q parallel to C D, cutting the diagonals E F and G H, at P, N, Q, O. Join P O and N Q, cutting C D at L and M; then I K is the transverse, and M L the conjugate axis of an ellipsis, that will be similar to the given ellipsis A D B C, which may be described by some of the foregoing methods.

PROBLEM XXXI.—*To describe a parabola.*

If a thread equal in length to B C be fixed at C, *Fig.* 32, the end of a square A B C, and the other end be fixed at F; and if the side A B of the square be moved along the line A D, and if the point E be always kept close to the edge B C of the square, keeping the string tight, the point or pin E will describe a curve E G I H, called a *parabola.*

Fig. 31.

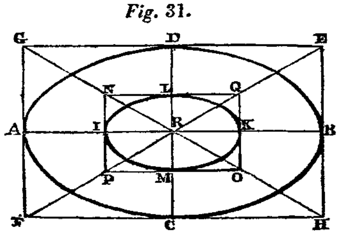
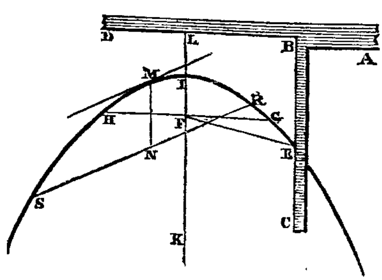


Fig. 32.



The *focus* of the parabola is the fixed point F, about which the string revolves.

The *directrix* is the line A D, which the side of the square moves along.

The *axis* is the line L K, drawn through the focus F, perpendicular to the directrix.

The *vertex* is the point I, where the line L K cuts the curve.

The *latus rectum* or *parameter*, is the line G H passing through the focus F, at right angles to the axis I K, and terminated by the curve.

The *diameter* is any line M N, drawn parallel to the axis I K.

A *double ordinate* is a right line R S, drawn parallel to a tangent at M, the extreme of the diameter M N, terminated by the curve.

The *abscissa* is that part of a diameter contained between the curve and its ordinate, as M N.

Problem XXXII.—*To describe a parabola, by finding points in the curve; the axis* A B, *or any diameter being given, and a double ordinate* C D.

Through A draw E F, *Fig.* 33, parallel to C D; through C and D draw D F and C E parallel to A B, cutting E F at E and F. Divide B C and B D, each into any number of equal parts, as four; likewise divide C E and D F into the same number of equal parts. Through the points 1, 2, 3, &c. in C D, draw the lines 1 *a*, 2 *b*, 3 *c*, &c. parallel to A B; also through the points, 1, 2, 3, &c. in C E and D F, draw the lines 1 A, 2 A, 3 A, cutting the parallel lines at the points *a*, *b*, *c*; then the points *a*, *b*, *c*, are in the curve of the parabola.

Problem XXXIII.—*To describe an hyperbola.*

If B and C, *Fig.* 34, be two fixed points, and a ruler A B be made movable about the point B, a string A D C being tied to the other end of the rule, and to the point C; and if the point A be moved round the centre B, towards G, the angle D of the string A D C, by keeping it always tight, and close to the edge of the ruler A B, will describe a curve D H G, called an hyperbola.

Fig. 33.

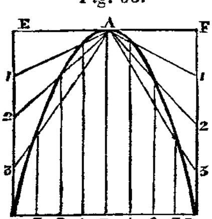


Fig. 34.

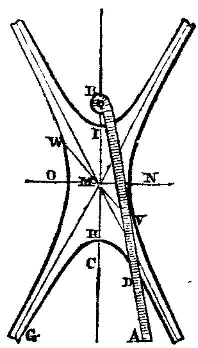
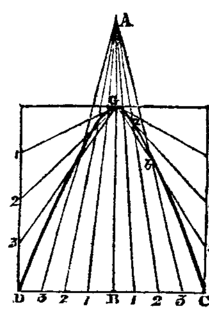


Fig. 35.



If the end of the ruler at B were made movable about the point C, the string being tied from the end of the rule A to B, and a curve being described after the same manner, is called an *opposite hyperbola*.

The *foci* are the two points B and C, about which the ruler and string revolve.

The *transverse axis* is the line I H terminated by the two curves passing through the foci, if continued.

The *centre* is the point M, in the middle of the transverse axis I H.

The *conjugate axis* is the line N O, passing through the centre M, and terminated by a circle from H, whose radius is M C, at N and O.

A *diameter* is any line V W, drawn through the centre M, and terminated by the opposite curves.

Conjugate diameter to another, is a line drawn through the centre, parallel to a tangent with either of the curves, at the extremity of the other diameter terminated by the curves.

Abscissa is when any diameter is continued within the curve, terminated by a double ordinate and the curve; then the part within is called the abscissa.

Double ordinate is a line drawn through any diameter parallel to its conjugate, and terminated by the curve.

Parameter, or *latus rectum*, is a line drawn through the focus, perpendicular to the transverse axis, and terminated by the curve.

Problem XXXIV.—*To describe an hyperbola by finding points in the curve, having the diameter or axis* A B, *its abscissa* B G, *and double ordinate* D C.

Through G draw E F, *Fig.* 35, parallel to C D; from C and D draw C E and D F, parallel to B G, cutting E F in E and F. Divide C B and B D, each into any number of equal parts, as four; through the points of division, 1, 2, 3, draw lines to A. Likewise divide E C and D F into the same number of equal parts, viz. four; from the divisions on C E and D F, draw lines to G; a curve being drawn through the intersections at G, *a*, *b*, &c. will be the hyperbola required.

GILDING. The art of applying to various substances an extremely thin coating of gold. If the substances to be gilt be metallic, this is effected by simple adhesion of the surfaces; but if not, the gold is attached by means of some adhesive medium. The simplest of all the kinds of gilding on metal is that by which copper or silver wire is gilt. The bar, before it is given to the wire drawer, is plated with gold by having several layers of gold leaf burnished down upon them whilst hot; and being then subjected to the stronger compression which takes place in wire drawing, the gold and the other metal become so perfectly united as to form, in fact, one substance; but the most usual way of covering the face of metals with gold is by means of an amalgam, or, as it is technically termed, water gilding. If the metal to be gilt be silver, it is first soaked in warm muriatic acid, that the surface may be rendered perfectly clean, and then washed in clean water, changed two or three times to get rid of the whole of the acid; being afterwards dried and made moderately warm, a little gold amalgam, also warm, is to be carefully and evenly spread upon the silver, to which it will immediately adhere. The plate is then placed upon a convenient support over a charcoal fire, and the mercury is driven off by heat, when the plate will be found entirely covered with a thin coating of pale dull gold. The small roughnesses are now to be removed with a scratching brush, composed of extremely fine brass wire, which renders the surface perfectly smooth and bright; after which the colour is heightened by warming the piece and smearing it over with gilder's-wax, which is a composition of bees'-wax, red ochre, verdigris, and alum. The wax being burnt off over a charcoal fire, and the piece quenched in urine, the colour of the gilding will be found to be much heightened, after which it may be burnished or not, as may be desired. The affinity of copper and its alloys not being so great as that of silver for mercury, the adhesion of the amalgam is promoted by the action of nitric acid in the following manner:—the piece of copper, a button for instance, after being cleaned and burnished, is dipped in a solution of nitrate of mercury, which, owing to the superior affinity of the copper for the nitric acid, is quickly decomposed, and the mercury becomes deposited in a metallic state over the whole surface of the copper, to which it strongly adheres; the gold amalgam is now applied, and the rest of the process goes on as already described. Gilding is rarely applied to other metals than silver, copper, and the alloys of the latter metal. There are two methods of gilding wood, viz., oil gilding and burnished gilding. Oil gilding is thus performed:—the wood is first primed or covered with two or three coatings of boiled linseed oil and white lead, to fill up the pores of the wood, and to render the surface smooth and even. When the priming is quite dry, a thin coat of gold size must be laid on; this is prepared by grinding together some strongly calcined red ochre with the thickest drying oil that can be procured; and previous to using it, it must be mixed with

a little oil of turpentine, that it may work freely. When the gold size is sufficiently dry, leaf gold, cut into strips, is taken up by the point of a fine brush and applied to the parts to be gilded, and is then gently pressed down by a ball of soft cotton; the gold instantly adheres to the sticky surface, and, after a few minutes, the dexterous application of a camel's-hair brush sweeps away the loose particles of gold leaf without disturbing the rest. In a day or two the size will be perfectly dry, and the operation is then finished. This method is simple and durable, but will not admit of burnishing, and therefore wants the high lustre produced by the next process: it is chiefly used for out-door work. Burnished gilding, or gilding in distemper, is thus performed:—the surface to be gilt must be first covered with a thick coating of strong parchment size; this coating being dried, eight or ten more must be applied, consisting of the same size, mixed with fine plaster of Paris or washed chalk; and when the whole is perfectly dry, a moderately thick layer must be applied of size, mixed with bole or yellow ochre. While this last is yet moist the gold leaf is to be put on in the usual manner; it will immediately adhere on being pressed by the cotton ball, and before the size is perfectly dry, those parts which are intended to be most brilliant are to be carefully burnished with an agate or dog's tooth. This kind of gilding will not withstand rain or even damp, and is therefore only applied to in-door work, as picture frames, &c.; it may be cleaned with a soft brush and hot spirit of wine, or oil of turpentine.

GIMBALS, in Sea Affairs, the brass rings by which a sea compass is suspended in its box, forming a universal joint upon the principle of Hooke's, so as to counteract the effect of the ship's motion, and to keep the card horizontal.

GIN, in Mechanics, a machine for driving piles, fitted with a windlass and winches at each end, at which eight or nine men heave the rope from the barrel or windlass, passing over the wheel at the top.

GLAIR. The white of eggs used as a varnish for paintings; for this purpose it is beaten to an unctuous consistence, and commonly mixed with a little spirit of wine to make it work freely, and a little lump of sugar, to give it body and prevent it from cracking; it is then evenly spread over the picture with a fine brush.

GLASS. A well-known transparent and brittle factitious substance, of which the basis is silica, brought into complete fusion by the addition of one of the fixed alkalies. There are several different kinds of glass, adapted to different uses. The best and most beautiful, are the flint and the plate glass; these, when well made, are perfectly transparent and colourless, heavy and brilliant. They are composed of fixed alkali, pure silicious sand, calcined flints, and litharge, in different proportions. The flint glass contains, likewise, a large quantity of oxide of lead, which, by certain processes, is easily separated.

Crown glass is that used for windows, and is made without lead, chiefly of fixed alkali fused with silicious sand, to which is added some black oxide of manganese, which is apt to give the glass a tinge of purple.

Bottle glass is the coarsest and cheapest kind; into this little or no fixed alkali enters the composition: in this country it is composed of sand, and the refuse of the soap boiler, which consists of the lime employed to render his alkali caustic, and of the earthy matters with which the alkali was contaminated. The most fusible is flint glass, and the least fusible is bottle glass; flint glass melting at the temperature of 10° Wedgwood, crown glass at 30°, and bottle glass at 47°. Although glass when cold is exceedingly brittle, when heated to redness it becomes one of the most ductile bodies known, and may be drawn into threads so very delicate as to become almost invisible to the human eye: it is extremely elastic, and one of the most sonorous of bodies. In making glass, the materials undergo a preparatory process called *fritting*, which consists in mixing them in the proper proportions, and submitting them to a moderate heat for six hours, by which they are reduced to a pasty consistence, and form what is called frit, which is cut into squares, and stored up for use; and as the quality of the glass depends upon the age of the frit, the principal manufacturers endeavour always to keep a considerable stock of frit on hand. This

frit is introduced into large pots made of prepared clay, and in these is exposed to a heat sufficient to melt it completely. When the fusion has continued the proper time, the furnace is allowed to cool a little; in this state the glass is exceedingly ductile, and will assume any shape, according to the fancy of the workman. The vessels thus formed must not be permitted to cool very quickly; hence they are put into a furnace, that the heat may pass off very gradually, and this is called "annealing." Having said thus much to give a general idea of the process, we shall now proceed to describe, somewhat in detail, the manual operations in the manufacture of glass; observing that, owing to the excise laws, the different branches of the manufacture, viz. crown, flint, plate, and bottle glass, are not carried on at the same works, but require to be in separate establishments; we shall, therefore, select for description the manufacture of flint glass, by which the various utensils in glass are produced. The other branches differ principally in the number and arrangement of the furnaces; but in all of them, with the exception of plate glass, the glass is brought into the desired form principally by means of a blowing pipe: the operation is exceedingly simple: the workman has a tube of iron, the end of which he dips into a pot of melted glass, and thus gathers a small quantity of it on the end of the tube; he then applies the other end of the tube to his mouth, and blows air through it; this air enters into the body of the fluid glass, and expands it out into a hollow globe similar to the soap bladders blown from a tobacco pipe, and by varied management of these globes while in a soft state, and with the aid of a few simple tools, they are reduced into the forms of the different vessels in common domestic use. The first thing to be described is the furnace: it consists of two large domes set one over the other; the lower one stands over a long grating, which is on a level with the ground; on this grating the fuel is laid, and beneath it is a large arch, by which the air is admitted, and by which the ashes may be removed. In the sides of the lower dome as many holes or mouths are made as there are workmen to make use of the furnace, and before each mouth a pot of melted glass is placed; the pots are very large, like crucibles, and will hold from three to four hundred-weight of liquid glass; they are supported upon three small piers of brickwork, resting on the floor of the furnace. The form reverberates the flame from the roof down upon the pots, and they are placed at some distance within the furnace, that the flame may get between the wall and the pots. The upper dome is built upon the other, and its floor made flat by filling up round the roof of the lower dome with brickwork; there is a small chimney opens from the top of the lower dome into the middle of the floor of the upper one, which conveys the smoke away from it, and a flue from the upper dome leads it completely from the furnace; the upper dome is used for annealing the glass, and is exactly similar to a large oven; it has three mouths, and in different parts a small flight of steps leads up to each. The implements employed in the formation of glass vessels are few and simple; the following are the principal: a blowing-pipe, which is simply a tube of wrought iron about three feet long, and covered with twine towards the mouth-piece, pliers and calliper compasses, a pair of common shears to cut the glass, a very coarse flat file, and several small iron rods; there is also a bench or stool with two arms, another stool or table with a smooth cast-iron plate upon it, and upon the ground behind this stool is another plate of iron.

We shall now proceed to describe, somewhat more minutely, the manufacture of flint glass. The melting pots are charged with frit, thrown in by shovelsful from time to time, allowing each portion to melt before a fresh quantity is added. When the whole is converted into a clear transparent glass, and is become perfectly pure and free from particles of sand or bubbles of air, the gatherers and blowers commence operations, and continue working night and day until the batch is exhausted. The process of blowing is varied according to the form of the piece to be manufactured; to illustrate it, it will be sufficient to describe the method in which a wine glass is formed. When the blower has received from the gatherer the blowing pipe charged with a sufficient quantity of metal, he seats himself in a chair provided with two arms or elbows,

one of which is plated with iron, and placing the blow pipe across the elbows, so that the heated end may rest on the iron plate, having first formed the glass into a hollow ball, he rolls the pipe backwards and forwards, and laying hold of the glass on the farther side of the ball with a small pair of pliers, draws it out to form the stalk of the glass, while the part next the blow pipe is fashioned into the bowl. In the mean time another blower, having formed a smaller ball, opens it by a sharp cut, and presses it while red hot against the end of the stalk held by the former workman, to which it immediately adheres; the workman then with a piece of iron, which he wets with his mouth, touches the globe intended for the bowl of the glass, which is still very hot, although so much chilled as to retain its shape; in a second or two it cracks all round, and by giving it a gentle knock it is detached from the blowing pipe. The workman then instantly heats it, and with a pair of shears cuts the mouth smooth and even; but as the shears have put the glass out of the circular form, he heats it again, and by a dexterous twirl and swing round his head gives it the desired shape almost without the use of any tools. The wine glass now finished, the iron at the foot is detached by a smart blow, and the glass is carried by a boy, upon a long forked iron, to the annealing oven. After the glass is annealed it may be required to be cut before it is ready for sale: this, when the articles are small, and can be easily held in the hand, is performed upon small grit grindstones, or by circular plates of iron, revolving in troughs of sand and water; and for beaded mouldings, as upon decanters, a corresponding groove is formed upon the periphery of the plate. The operations are concluded by polishing the cut parts by means of revolving straps covered with polishing powder.

In the manufacture of bottle glass, after the metal is brought into fusion, which requires an intense heat during eighteen hours, it is reduced to the working temperature, which is steadily maintained by a due supply of fuel, and being scummed, is ready for blowing. For carboys and similar articles it is merely blown into a globular form; but for common wine bottles, or for square or octagonal bottles or jars, it is blown within moulds. Each piece, as it is blown, is handed over to the finisher, who forms the ring at the mouth of the neck, and delivers it to a boy, to be placed in the annealing oven.

In making crown glass, as soon as the metal is ready for blowing, a workman gathers on the blowing pipe a quantity of metal sufficient for forming a sheet or table of glass, which he blows, and, by frequent rolling on a polished table, brings it into a globular or cylindrical form; he then inflates it gently into an oblong ball called a *parisienne*, and immediately heats it again at the mouth of the furnace, in order farther to expand it; in this stage a solid iron rod, charged with melted glass, is made to adhere to the centre of the expanded part opposite the extremity of the blow pipe, and this latter is detached from the glass by a cold iron, leaving an orifice, which is gradually enlarged by heating the glass at the small hole of the flashing furnace, and afterwards at the larger hole of the same furnace, the workman all the while wheeling the rod which supports the glass on a hook in a cross wall, built to defend him from the heat. By degrees, in consequence of the heat and the centrifugal motion, the opening of the glass is continually enlarged, until it expands suddenly with great violence into the form of a large circular plate, four or five feet in diameter, and of uniform thickness, except at the centre, where it is attached to the supporting iron; from this iron it is separated by the application of cold, leaving in the centre a thick nodule called the bull's eye; and when the plate is sufficiently firm to prevent warping, it is carried to the annealing oven and placed on its edge in a proper frame, to keep it flat till all the tables are ready for removal into the crates in which they are kept.

Plate glass is formed either by blowing or casting: by the former method is made the glass for carriage windows; and by the latter, the large plates for looking glasses. Of late it is said that the art of blowing plate glass has been so much improved, that plates measuring 60 inches in length by 21 in breadth have been produced by this method; but by casting, much larger plates are produced, and the establishment at Ravenhead has exhibited at their warehouse

near Blackfriars' Bridge plates of the extraordinary dimensions of 12 feet by 6. The most perfect furnace for manufacturing plate glass appears to be that which is employed in France. It consists of a central melting furnace of an oblong form, with a double arched roof; it is capable of containing, upon a raised bench on each side of the fire grate, two large melting pots and a cistern; in each angle of the furnace, and on each side, are two or three openings for introducing the materials, transferring the melted metal from the pots to the cistern, and withdrawing the latter when filled with metal: at each angle of the principal furnace is another of an oblong form communicating with the central one by flues, through which the flame reflecting from the arches of the melting furnace reverberates on their contents. Each of these smaller furnaces has two openings, a smaller one for producing a current of air, and a larger one for introducing and removing what is placed within them. Three of them are usually employed for burning the melting pots and cisterns, which are made of fire-clay; and the fourth is used for preparing the frit. Around the plate glass house are several annealing furnaces like baker's ovens, with capacious mouths. For receiving the melted metal from the pots, square cisterns of sufficient capacity to contain melted metal enough for one plate are used, and when these are filled they are withdrawn from the furnace by means of large iron tongs, supported upon an axle running upon two wheels; another pair of tongs made to encompass the cistern by entering a groove on its sides, and furnished at each end with a handle for the more convenient management of it, is attached by four chains to a sort of crane for suspending and raising the cistern into a proper position with regard to the table. The casting table consists of an oblong frame of wood, covered on its upper surface with a thick sheet of smooth copper, having at its sides two iron rulers of the thickness of the intended plate, their distance asunder being regulated by the proposed breadth of the plate. An iron roller of considerable weight, furnished with a handle at each end, resting on the iron rulers at one end of the table, is made to pass over the melted metal when poured upon the table, in order to form it into a plate of uniform thickness. The apparatus just described is used only for *casting* plate glass, that for blowing being so simple as to need no particular description. In preparing the materials for plate glass they are first reduced to powder, well mixed together and calcined in the fritting furnace before described; they are then removed as quickly as possible into the melting pots previously heated, and after being melted, which generally requires about ten hours, the heat is continued at its utmost degree till the metal becomes perfectly fine; it is then ladled from the pots into the cisterns, which are then drawn out on projecting ledges, and conveyed to the casting table, over which they are suspended by the crane, and by means of the handles of the tongs they are inclined so as to allow their contents to flow over the table: the iron roller is then immediately passed steadily over the surface of the melted metal, sweeping off the superfluous matter into troughs placed at the sides of the table; and when the roller reaches the further extremity of the table, it is expeditiously lowered on a tressel, which prevents its interfering with the plate. The operation of casting is performed before the mouth of the annealing oven, in which it remains exposed to a moderate heat for fourteen days, the heat being at last suffered to die away as gradually as possible. When quite cool it is withdrawn, carried to the magazine, examined, and cut square by a glazier's diamond, and is then ready for the operations of grinding and polishing. The casting table and tressel, as also the crane, are all mounted upon wheels, for the convenience of removing them from one annealing furnace to another. When plate glass is made by blowing instead of casting, after the materials have been fused as before described, and become fine, the further admission of air is prevented by closing all the openings of the furnace, and every thing is suffered to remain stationary for nine or ten hours. This gradual cooling has been found necessary, to enable the melted glass to adhere sufficiently to the blowing pipe. The mode of blowing plate glass greatly resembles that used in the manufacture of table glass, except in the quantity of metal gathered on the blowing pipe, which is sometimes nearly 100lbs. When plates of the largest size are to be

formed, the metal is gradually blown and worked into the form of a cylinder, which is cut open at one side with a pair of shears, and the soft glass is spread on a heated floor, covered with a thick stratum of sand, and from thence is speedily conveyed to the annealing furnace. In grinding plate glass, two plates are always ground together, one being imbedded in plaster of Paris upon a table, whilst the other, also imbedded in plaster, is placed upon the former, and being loaded with great weights, is moved uniformly but pretty quickly over its surface. Sand moistened plentifully with water is from time to time sprinkled between the plates, and grinds away all the prominences of the glass until both plates become smooth and even. As the grinding proceeds, sand of greater fineness is employed; and towards the conclusion, it is exchanged for emery, also of varying fineness. As by grinding the surface is roughened and rendered incapable of transmitting the rays of light, it becomes necessary to restore its lustre by polishing, which is performed by rubbing the surface with a block of wood, covered on the lower side with a woollen cloth. The workman keeps it supplied with fine polishing powders, as tripoli and putty, changing from coarse to fine, as the polishing advances to a conclusion. To regulate the pressure a springing pole is put on the back of the block, which, being bent to a curve, is supported from the ceiling of the workshop.

GLASS, (Soluble.) A simple silicate of potassa or soda, which unites perfect solubility in boiling water to some of the general properties of common glass. In the liquid state, it may be applied to cloth or wood, for the purpose of rendering them incombustible. In fact, by the evaporation of the water in which it is dissolved, a layer of a substance capable of fusing when heated, is deposited on these bodies, that protects them from the contact of air necessary for their combustion. The following account of its manufacture and uses is derived from a translation by Professor Renwick, of the *Traité de Chimie appliqué aux Arts, par M. Dumas.*

Preparation.—Soluble glass may be obtained by dissolving pure silica, obtained by precipitation, in a boiling solution of caustic potassa; but this process, being both inconvenient and costly, cannot be practised upon a large scale. When sand and carbonate of potassa are heated together, the carbonic acid is never wholly driven off, except when the sand is in excess; but the whole of the carbonic acid may be expelled by adding powdered charcoal to the mixture, in such proportion that the carbonic acid of that part of the carbonate which is not decomposed may meet with a sufficient quantity of carbon to convert it into carbonic oxide. In this way the silica first forms a silicate in the proportions contained in common glass, and drives off the appropriate equivalent of carbonic acid; then, at a high heat, the rest of the carbonate of potassa is decomposed by the carbon, the carbonic oxide escapes, and the potassa thus freed, either sublimes, or combines with the glass already formed.

The sand (freed from lime and alumina) and carbonate of potassa (pearl ash) are taken in the proportion of 2 of the latter to 3 of the former, and to 10 parts of pearlash and 15 of sand, 4 parts of charcoal are added. A less portion of charcoal must not be taken; on the contrary, if the form of potash employed be not sufficiently pure, a larger proportion of charcoal may be advantageously employed. This substance accelerates the fusion of the glass, and separates from it all the carbonic acid, of which there would otherwise remain a small quantity that would have an injurious effect. In other respects, the same precautions that are employed in the manufacture of common glass are to be observed. The materials must be first well mixed, then fritted, and finally melted in a glass pot, until the mass becomes liquid and homogeneous. The melted matter is taken out of the pot with an iron ladle, and the pot is then filled with fresh *frit.* Thirty pounds of pearlash, 45 of sand, and 12lbs. of powdered charcoal may be taken for a charge; with this quantity the heat must be continued for five or six hours. The crude glass thus obtained, is usually full of air bubbles; it is as hard as common glass, of a blackish gray colour, and transparent at the edges; sometimes it has a colour approaching to whiteness, and at others is yellowish or reddish: these are indications that the quantity of charcoal has

not been sufficient. If it be exposed for some weeks to the air, it undergoes slight changes, which rather tend to improve than injure its qualities. It attracts a little moisture from the air, which slowly penetrates its mass, without changing its aggregation or its appearance; it merely cracks; and a slight efflorescence appears at its surface. If it be exposed to heat, after it have undergone this change, it swells up, owing to the escape of the aqueous matter it has absorbed. In order to prepare it for solution in boiling water, it must be reduced to powder by stampers; if this were not done, it would dissolve too slowly. One part of glass requires from 4 to 5 of water for its solution. The water is first heated to ebullition in an open boiler, the powdered glass is then added by degrees, and must be continually stirred, to prevent it from adhering to the bottom. The ebullition must be continued three or four hours, until no more glass is dissolved: the liquor will then have acquired the proper degree of concentration. If the ebullition be checked before this state is attained, carbonic acid will be absorbed by the potassa from the air, which will produce an injurious effect; for the same reason, too great a quantity of water must not be employed, for during the long evaporation which will then become necessary, the carbonic acid of the water will readily combine with the potassa, and cause a precipitation of the silica. When the liquor becomes too thick, before the whole of the glass is dissolved, boiling water must be added. When the solution has acquired the consistence of syrup, and a density of 1.24 to 1.25, it is sufficiently concentrated, and fit for use. It is then permitted to rest, in order that the insoluble parts may be deposited; while it is cooling, a pellicle forms upon the surface, which after a time disappears of itself, or may be redissolved by depressing it in the liquor. This pellicle begins to appear during the ebullition, and indicates its concentration. When the crude glass is of a proper composition it contains but a few saline impurities, and no sulphuret of potassium, it may be treated in the way we have described; but if it contain any notable proportion of these substances, they must be separated before it is dissolved; this separation may be effected in the following manner:—The powdered glass is exposed to the action of the air for three or four weeks, during which time it must be frequently stirred; and if it run into lumps, which will happen in moist weather, they must be broken up. The glass, as we have stated, attracts moisture from the air, and the foreign substances either separate or effloresce. It then becomes easy to remove them from the glass. It is sprinkled with water, and frequently stirred. At the end of three hours the liquor is removed, it will then contain a part of all the saline impurities, and a little of the silicate of potassa; the powder is again to be washed with fresh water. Soluble glass thus treated readily dissolves in boiling water, and the solution leaves nothing to be desired. To preserve it in the liquid form no particular care is necessary, as even after a long space of time it undergoes no perceptible change, if the solution have been properly prepared. The only precaution is not to allow air too free an access to it. A similar product may be obtained by using a carbonate of soda instead of one of potassa. In this case, two parts of the soda of the shops is required for one of silica. This glass has the same properties as the other, but is more valuable in its uses. The solutions of these two kinds of glass may be mixed in any proportion whatever, and this mixture is more serviceable in some cases, than either of them separately.

Properties.—Soluble glass forms a viscid solution, which when concentrated becomes turpid and opalescent: it has an alkaline taste and reaction. The solution mixes in all proportions with water. When the density of the solution is 1.25, it contains nearly 28 per cent. of glass; if the concentration be carried beyond this point, it becomes so viscid that it may be drawn out in threads like molten glass. Finally, the liquor passes to the state of a vitreous mass, whose fracture is conchoidal; it then resembles common glass, except in hardness. When the solution is applied to other bodies, it dries rapidly at common temperatures, and forms a coat like a varnish. Soluble glass when dried does not undergo any perceptible change when exposed to the air, nor does it attract from it either moisture or carbonic acid; neither has the carbonic

acid of the atmosphere any well marked action on the concentrated solution; but when a current of carbonic acid is passed through the solution, the glass is decomposed, and hydrate of silica deposited. But a weak solution becomes turbid on exposure to the air, and is after a time decomposed wholly. When the glass is impure, an efflorescence is formed after a while, which may be produced either by the carbonate and hyposulphate of potassa, or by chloride of potassium. Soluble glass dissolves gradually without residuum in boiling water; but in cold water the solution is so slow as to have led to a belief that it does not dissolve at all. It however never becomes entirely insoluble, except when it contains a much larger proportion of silica, or when it is mixed with other bodies, such as the earths, metallic oxides, &c., with which double or triple salts are formed, as is the case in the common glasses. Soluble glass which has been exposed to the air, and is afterwards submitted to the action of heat, swells and cracks at first, and melts with difficulty; it then loses about 12 per cent. of its weight. It therefore contains, even when solid, a considerable quantity of water, which it does not lose when simply dried by exposure to the air. Alcohol precipitates it unaltered from its solution in water. When the solution is concentrated, but little alcohol is required for precipitation, and it need not be highly rectified. Pure soluble glass may therefore be easily obtained from an impure solution by the use of alcohol. The alcohol being added, the gelatinous precipitate is permitted to settle; the supernatant liquor is decanted, the precipitate collected, rapidly stirred after the addition of a little cold water, and subjected to pressure. In truth, however, this process is attended with some loss, for even cold water will rapidly dissolve the precipatated glass in consequence of its minute division. The acids decompose the solution of glass. They also act upon it when solid, separating the silica in the form of powder.

Uses.—The properties of soluble glass fit it for numerous and varied applications. It has been used in the theatre of Munich as a means of safety from fire. All sorts of vegetable matter, wood, cotton, hemp, linen, paper, &c. are, as is well known, combustible; but in order that they shall burn, two conditions are requisite, an elevated temperature, and free contact of air, to furnish the oxygen necessary for their transformation into water and carbonic acid. When once set on fire, their own combustion develops the heat necessary to keep up the chemical action, provided they be in contact with air. If deprived of such contact, and made red hot, they will, it is true, yield inflammable volatile products, but the carbon which is left will not burn, as it is deprived of air, and thus the combustion will stop of itself. Such is the part which all the fixed fusible salts are capable of performing, if they be, in addition, composed of substances incapable of yielding their oxygen at a low red heat, to either carbon or hydrogen. These salts melt as the vegetable matter becomes heated; they form upon it a coat impenetrable to the air, and either prevent altogether, or limit its combustion. The phosphate and borate of ammonia have such a character, but they are so readily soluble in cold water, as to be liable to objections which cannot be urged against soluble glass. Although soluble glass is of itself a good preservative from fire, it fulfils the object better when it is mixed with another incombustible body in powder. In this case the solution of glass acts in the same manner as the oil of painters. The several coats have more body, become more solid, and more durable; and if the substance which is added be of proper quality, coagulate by the action of fire into a strongly adhesive crust. Clay, whiting, calcined bones, powdered glass, &c. may all be employed for this purpose; but we cannot yet say with certainty which of them is to be preferred. A mixture of clay and whiting appears to be better than either used separately. Calcined bones form with soluble glass a very solid and adhesive mass. Litharge, which, with the glass, makes an easily fusible mixture, does not give a product fitted for coating wood, as the mixture contracts in drying; it therefore cracks, and is easily separated. Flint glass and crude soluble glass are excellent additions. The latter ought to be exposed to the air after it is pulverized, in order to attract moisture. If it be mixed with the solution, and be then applied to any body whatever it in a short time forms a

coating as hard as stone, which, if the glass be of good quality, is unalterable by exposure, and resists fire admirably. The scoriæ of iron and lead, felspar, fluor, may all be employed with soluble glass; but experience alone can decide which of these substances is best, and in what proportion they are to be employed. We should advise that the first coat should always be a simple solution of the glass; and that a similar solution be applied over coats composed of its mixture with other substances, particularly when such a coat is uneven and rough. The last named substances form a solid and durable coating, which suffers no change by exposure to the air, does not involve any great expense, and is readily applied; but, in order that it may not fail, particular care is to be taken both in preparing and employing it. In order to cover wood and other bodies with it, the solution must be made of a pure glass, for otherwise it would effloresce and finally fall off. However, a small degree of impurity is not injurious, although after a few days a slight efflorescence will appear; this may be washed off by water, and will not show itself a second time. When a durable covering is to be applied to wood, too strong a solution must not be employed at first; for in this case it will not be absorbed, will not displace the air from the pores, and in consequence will not adhere strongly. It is a good plan to rub the brush several times over the same place, and not to spread the coating too lightly. For the last coats a more concentrated solution may be employed; still it must not be too thick, and must be spread as evenly as possible. Each coat must be thoroughly dry before another is applied; and this will take, in warm and dry weather, at least twenty-four hours. After two hours the coat appears to be dry, but is still in a state to be softened by laying on another. The same inconvenience will then arise, which occurs when a thick coat of a concentrated solution is applied; the coat will crack, and does not adhere. This, however, is only the case when potassa is the base of the glass, for that formed from soda does not appear to crack. In applying soluble glass to the woodwork of the theatre at Munich, 10 per cent. of yellow clay (*ochre?*) was added. After six months, the coat had suffered but little change; it was damaged only in a few places where it had need of some repair. This arose from a short time only having been allowed for the preparation and application of the glass, and they were therefore done without proper attention. When this mode is employed for preserving a theatre from fire, it is not enough to cover the woodwork, it is also necessary to preserve the scenery, which is still more exposed to danger. None of the methods yet proposed for this purpose appears as advantageous as soluble glass, for it does not act upon vegetable matter, and completely fills up the spaces between the thread; it fixes itself in the web in such a way that it cannot be separated, and increases the durability of the fabric. The firmness which it gives to stuffs does not injure them for use as curtains, because it does not prevent them from being easily rolled. So far as the painting of scenes is concerned, the glass forms a good ground for the colours. To prevent the changes which some colours, Prussian blue and lake for instance, might undergo from the alkaline matter, it will be necessary, before painting, to apply a coat of alum, and then one of whiting. There is no great difficulty in applying soluble glass to cloths; still this operation is not so easy as might at first be imagined. It is not sufficient to coat or dip them in the solution; they still require after this operation to be subjected to pressure. This object might perhaps be best attained by passing them between rollers plunged in the solution. When a cloth is only coated with soluble glass, and put into the fire, it will remain incandescent after it is taken out. This is not the case when it has been properly impregnated with this solution. A still better purpose is answered in this case, when litharge has been added to the solution. The stuff in drying yields to the shrinking of the mixture, and becomes inseparable from it, which is the reverse of what happens when it is applied to wood. A single part of litharge in fine powder is sufficient for fourteen parts of concentrated liquor. Soluble glass is capable of many other applications, and particularly as a cement; for this use it is superior to all those which have hitherto been employed for uniting broken glass, porcelain, &c. It may be used in place of

glue or isinglass in applying colours, although when employed by itself it does not make a varnish which will preserve its transparency when in contact with air.

GLAUBER SALT. The sulphate of soda.

GLAZING, as it is now practised, embraces the cutting of all the varieties of glass manufactured for windows, together with fixing it in sashes by means of brads and a stopping of putty; also the forming of casements, and securing the glass by bands of lead fastened to outside frames of iron. The most ancient species of glazing was in head-work, as our numerous cathedrals and religious houses still extant demonstrate; and fixing glass in leaden frames is still continued for the same description of buildings. The business of a glazier, if considered in its most simple operations, consists in fitting all the various kinds of glass manufactured and sold into sashes previously prepared to receive them. The sashes, as they are now made, have a groove or rebate formed on the back of their cross, and vertical bars adapted to receive the glass; into these rebates the glazier exactly fits the squares, which he beds in a composition called putty. The putty consists of pounded whiting beaten up with linseed oil, and so kneaded and worked together as to make a tough and tenacious cement, and is of great durability; this the glazier colours to suit the sashes he may have in hand; if they are common deal sashes, the putty is left and used as first manufactured; but if they are mahogany, it is coloured with ochre till it approaches more nearly that of the sashes. In glazing windows the colour of the glass is that on which the greatest beauty is given to the work; and to effect this successfully, many different manufactories have been established. The most usual kind of window glass now employed by the glaziers is called crown glass; it is picked and divided at the manufactory into the several different kinds, which are known as first, seconds, and thirds, and which particularly denote the qualities of the several kinds of glass, the first being known as best crown, the next in quality second crown, and the last, thirds, or third crown, the price of each varying according to the quality. The glass is in pieces called tables, of about three feet in diameter each, and, when selected and picked as above, they are packed in crates, twelve of such tables being put in each crate of best glass, fifteen in the seconds, and eighteen in the thirds.

Green glass is another of these species, and which is greatly in demand for all the purposes in which colour is not so particularly sought for. This sort of glass is used in the glazing of the windows of cottages, also for green and hot-houses, to which it is found to answer every purpose: it is not more than one-half the cost of the crown glass. The green glass appears to have been the most ancient kind made use of, as most of the vestiges remaining in the old windows approach very nearly in their quality to what is now sold under that designation. The glaziers also prepare the crown glass so as to produce an opaque effect, to prevent the inconvenience of being overlooked; it is technically called ground glass, which is not improper, inasmuch as it is rendered opaque by rubbing away the polish from off its surface, to do which the glazier takes care to have the sheets or panes of glass brought to their proper size; then they are laid down smoothly as well as firm, either on sand or any other substance which is adapted to admit of its lying securely; he then rubs it with sand and water, or emery, till the polish be completely removed; it is then washed, dried, and stopped into the window for which it was prepared. There was a species of glass made at Venice originally, which was manufactured wholly for this purpose, and is now to be seen in many counting-houses and old buildings; its general appearance presented an uneven surface, appearing as though indented all over with wires, leaving the intervening shapes in the form of lozenges. This glass was very thick and strong, and is of the description known as plate glass; it is now, however, generally substituted by the ground crown glass. A very beautiful plate glass is manufactured by the British Plate-Glass Company, at Ravenscroft, in Lancashire, and at their depôt in Albion-place, London, plates of every size, up to those of very great dimensions, may be obtained, the thickness varying from an eighth to a quarter of an inch. The cheapest kind of glazing is the old fashioned mode, in small squares of the diamond or

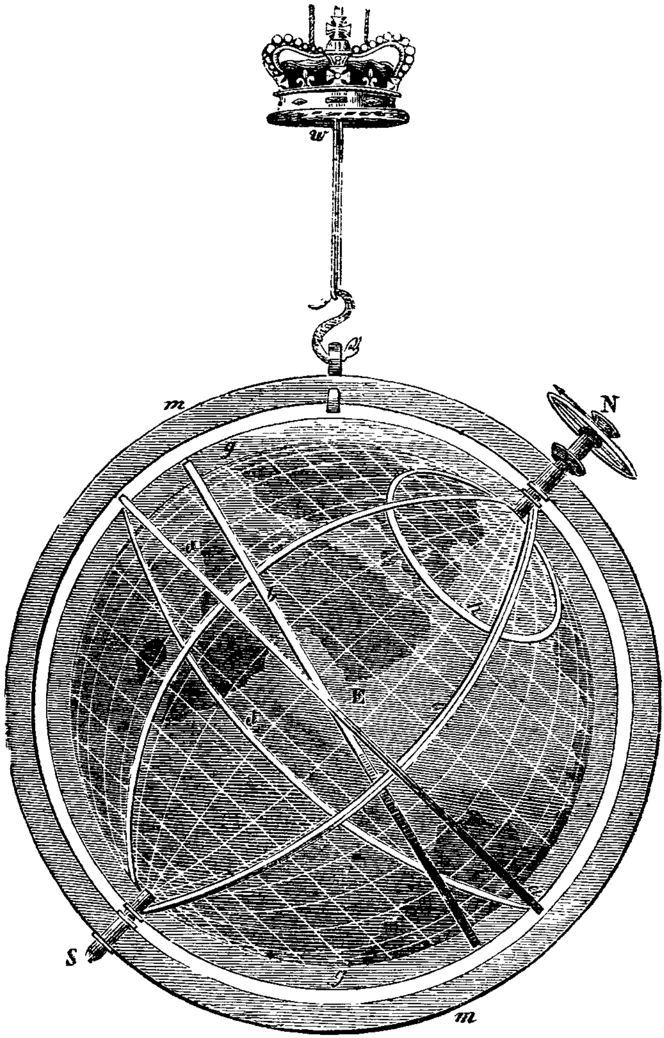
rhombus shape, technically called *quarries*, which are fixed in rebated leaden bars in outbuildings, cottages and in some kind of church windows. The lead for this purpose is cast and drawn through an instrument called a glazier's vice, which gives it the exact form required, and perfects the grooves for the reception of the quarries. These leads being cut to the proper lengths, they are soldered together at the intersections. This metal, which is used instead of the cross bars of sashes, is so soft as to be easily bent where the groove is left in it for the glass, and to be bent up again to inclose the glass after it is inserted. Window lights of this kind are further strengthened by vertical or horizontal bars of iron or wood, secured to them by bands of lead twisted around the bar. Glaziers now cut all their glass with a diamond; whereas, formerly, an instrument was made use of for the purpose, called a grozing-iron. The diamond used by glaziers is left in its natural state, or with its outward coat; when polished, it is said to lose its property, making a perfect fracture of the glass; it is fixed in lead, and secured by a ferrule in a handle of hard wood, and is used by drawing the diamond point over the glass, straight lines being effected by the assistance of a straight edge, also of hard wood. The other tools used by the glazier chiefly consist in "stopping-knives," for spreading the putty over the edges of the glass and rebates of the frames; in "hacking-out tools," which are strong-backed knives, capable of bearing the blows of a hammer, and used in clearing out the old putty, or making repairs; also in a pair of compasses, a three-foot rule, and a few other common tools, the uses of which require no explanation. New sashes should always be primed, that is painted once over before they are glazed, as the putty thereby holds much more firmly to the work.

GLOBE, or Sphere, in Geometry, a solid figure described by the revolution of a semicircle round its diameter, which remains unmoved; or it may be defined as a solid, bounded by a uniform convex surface, which is in every part equally distant from a point called the centre.

GLOBE, in Practical Mathematics, an artificial sphere, on which are represented the countries and seas of our earth, or the face of the heavens, the circles of the sphere, &c. That with the parts of the earth delineated upon it is called the "Terrestrial Globe," and that with the constellations of the heavens, the "Celestial Globe." These globes are mounted on frames with other appurtenances. Their principal use, besides serving as maps to distinguish the outward parts of the earth, and the situation of the fixed stars, is to illustrate the various phenomena arising out of the diurnal motion of the earth. The globes commonly used are constructed of plaster and paper in the following manner: a wooden axis is provided somewhat less than the intended diameter of the globe, and into the extremities iron wires are driven for poles; on this axis are applied two hemispherical caps, formed on a spherical wooden mould by pasting several sheets of paper on the mould one over the other to about the thickness of a crown piece, and cutting them through the middle when they are dried, and slipping them off the mould. They are now applied to the poles of the axis, and the two edges are sewed together with packthread. The rudiments of the globe thus laid, they proceed to strengthen it and make it regular. In order to do this the two poles are hasped in a metallic semicircle of the size intended, and a plaster made of whiting, water, and glue, well incorporated together, is daubed all over the surface; in proportion as the plaster is applied, the ball is turned round in the semicircle, the edge of which pares off whatever is superfluous, and beyond the due dimensions, leaving the rest adhering in places that are short of it; the ball is then set to dry, after which it is again set in the semicircle, and fresh plaster applied; and thus they continue to apply fresh composition, and to dry it, till the ball every where accurately touches the semicircle, in which state it is perfectly smooth and regular. The next thing is to paste the map on it: in order to this the map is projected in several gores or gussets, all of which join accurately on the surface, and cover the whole ball. To direct the application of these gores, lines are drawn by a semicircle on the surface of the ball, dividing it into a number of equal parts, corresponding to the number of gores, and subdividing those again answerably

to those of the gores. The paper thus pasted on, there remains nothing but to colour and illuminate the globe, and to varnish it, the better to resist dirt and moisture. The globe itself thus finished, is suspended in a brass meridian with an hour circle and a quadrant of altitude, and then fitted into a wooden horizon, which is supported by the legs of the frame.

Major Muller, G.L. has contrived a new arrangement of the globes, to which he has given the name of the cosmophere, and which forms the subject of the annexed engraving. The celestial globe consists of a hollow glass sphere, on



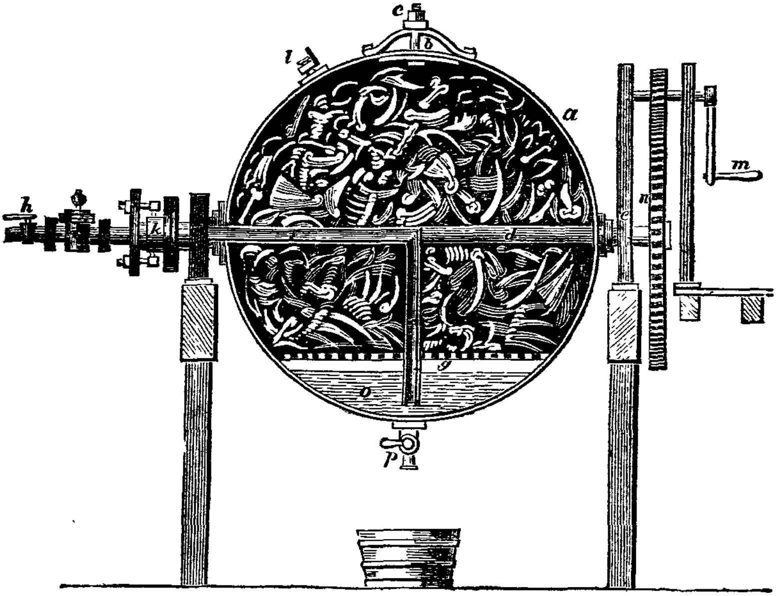
which are depicted the stars constituting the various constellations. This sphere is furnished with brass circles, representing the equinoctial, the ecliptic, the

colures, and the polar circles. The glass sphere separates at the equinoctial into two hemispheres, for the purpose of admitting within it a terrestrial globe, which is manufactured in the usual way: this globe is also furnished with brass circles, which are adjustable, to represent at pleasure the meridian and the horizon of any assigned place. The axis of the globe passes through the sphere, and supports both in a strong brass ring, which may be either attached to a stand, and made to rest upon a table, or suspended from the ceiling of a room, with a counterpoise *w*, as represented in the engraving, which will render the construction clear when compared with the following references. *a a* represents the equinoctials, where the two hemispherical glasses *g g* are united, and from which the declination of the stars is to be measured; *c* represents one of the colures, and *f* one of the terrestrial meridians; *h* one of the polar circles, and *m m* the large brass circle or general meridian, in which the apparatus is suspended by the poles N and S. By the cosmosphere, as we have described it, the position of the earth, with respect to the fixed stars, may be shown at any given time; and by placing on the celestial sphere patches to represent portions of the sun, moon, and planets, the position of the earth with respect to these bodies may also be represented with facility; hence many of the astronomical phenomena arising from the position of the earth, with regard to the other bodies, can be familiarly illustrated, and numerous useful problems readily solved. But to extend its usefulness, the patentee has made arrangements for removing the globe from the interior of the system, and placing in its stead the sun and planetary system; and by this means the relative positions of the planetary bodies may be interestingly represented. He has likewise provided brass graduated circles, by which, when they are attached to the celestial sphere, the nature of the various astronomical and nautical problems depending upon spherical trigonometry may be pleasingly explained.

GLUE. A tenacious viscid substance, used chiefly for binding or cementing pieces of wood together: it is usually prepared from the cuttings and parings of hides, and from the hoofs and horns of animals. For this purpose the materials are first steeped in water for two or three days, then well washed, and afterwards boiled to the consistence of a thick jelly, which is passed, while hot, through ozier baskets, to separate the grosser particles of dirt, bones, &c. from it, and then allowed to stand some time to purify it farther; when the remaining impurities have settled at the bottom, it is then melted and boiled a second time. It is next poured into flat frames or moulds, from which it is taken out pretty hard and solid, and cut into square pieces or cakes, and afterwards dried in the wind in a coarse kind of net. This is the ordinary method of preparing the common glue for carpenters' work; but some few years back Mr. Yardley, of Camberwell, obtained a patent for manufacturing glue from bones, which, as chemists have long known, contain nearly one-half their weight of solid gelatin, besides a considerable portion of fat. The glue thus obtained is said to be of very superior quality.

In the engraving on the next page *a* represents a section of the principal vessel of Mr. Yardley's apparatus, which is in the shape of a sphere or hollow globe of great magnitude, and made of cast or wrought iron; copper should not be used, as gelatin has a powerful action upon that metal. The first part of the process is to cleanse the bones by immersing them in a pit or cistern of water, where they are to remain about twelve hours; the water is then to be drawn off, and fresh water added to them; this operation may be repeated several times, to get rid of the adhering dirt. The water being withdrawn from the bones, a solution of lime, in the proportion of one bushel of the earth to five hundred gallons of water, is to be poured into the cistern for the more perfect cleansing of the bones, and the removal of superfluous matters. After three or four days' saturation the limy solution should be drawn off, and fresh water added, to get rid of the lime. Thus prepared, the bones are brought to the globular vessel *a* called the extractor, which is filled with them by removing the interior plate which covers the man-hole *b*; this aperture is of an elliptical form, and allows the plate (which is of a similar figure) to be slipped round and refixed in its place by turning the nut *c*, which draws it up tight against the

interior surface of the globular extractor; and the junctures are made air-tight by luting. The extractor turns upon a horizontal cylindrical shaft in the bearings *e e;* one-half of this shaft is made hollow, or consists of a strong tube *f f*, which tube also proceeds downwards from the centre of the vessel, to conduct the steam beneath the grating *g*, upon which the bones are laid. The steam, of



about 15 lbs. pressure to the inch, is admitted from the boiler by turning the cock *h*, and, passing along the pipe by the safety valve *i* and the stuffing box *k*, it enters and proceeds first to the bottom of the extractor, then rises up through the grating, and amongst the bones, until the vessel is completely charged; previous to this, however, the air contained in the vessel is got rid of by opening the cock *l* for the steam to blow through, and afterwards closing it. Whilst the steam is acting upon the bones the extractor is occasionally turned gently round by hand at the winch *m*, the shaft of which carries a small pinion that takes into the teeth of the wheel *n*, and the latter being on the same shaft as the extractor, consequently gives it a rotatory motion. When at rest, as shown, a quantity of fluid gelatin is collected in the bottom of the extractor at *o*, from whence it is discharged by the cock *p* into a tub beneath, after opening the air-cock *l* to allow it to run off. This done, steam is again admitted from the boiler into the extractor to act upon the bones for another hour, when the second portion of condensed liquor is to be drawn off. When the products thus obtained have become cold, the fat which has formed upon the surface is to be carefully removed by skimming, and the gelatinous portion only is to be returned into the extractor, by means of a funnel at the cock *l*. The steam is then re-admitted to the extractor for another hour, after which it is finally drawn off into another vessel to undergo a simple evaporating process, until it arrives at a proper consistency to solidify when cold, previous to which some alum is added to clarify it. When the gelatin has become cold and solid, it is cut out into square cakes, and dried as usual in the open air.

Mr. Bevan found that when two cylinders of dry ash, $1\frac{1}{2}$ inch in diameter, were glued together, and, after twenty-four hours, torn asunder, it required a force of 1260lbs. for that purpose, and consequently that the force of adhesion was

equal to 715 per square inch of surface. From a subsequent experiment on solid glue, he found that the cohesion is equal to 4000lbs. on the square inch, and hence infers, that the application of this substance as a cement is susceptible of improvement. Glue is frequently prepared for more delicate purposes in the arts from parchment or vellum cuttings, or from isinglass. Parchment glue is made by boiling gently shreds of parchment in water, in the proportion of one pound of the former to six quarts of the latter, till it be reduced to one quart. The fluid is then strained from the dregs, and afterwards boiled to the consistence of glue. Isinglass glue is made in the same way; but this is improved by dissolving the isinglass in common spirit by a gentle heat: thus prepared, it forms a cement much superior to paste for joining paper, or for stretching it on wood.

GLUTEN. A substance found combined with the feculent and saccharine matter, which constitute the principal part of nutritive grain. It is obtained in the largest quantity from wheat (amounting to the twelfth part of the whole grain) by kneading the flour into paste, which is to be washed very cautiously by kneading it under a jet of cold water till the water carries off nothing more, but remains colourless; what remains is gluten: it is ductile and elastic, and has some resemblance to animal tendon.

GOLD. A yellow metal of specific gravity 19.3, which is greater than any other body in nature, except platina. It is soft, very tough, ductile, and malleable, unalterable and fixed, whether in the atmosphere or in the heat of the hottest furnaces; but it has been volatilized by powerful burning mirrors, as also by the oxy-hydrogen blow pipe. No acid acts readily upon gold, except the nitro-muriatic acid, called aqua regia, in which it may be dissolved, occasioning at the same time an effervescence; but from the slight affinity of gold for oxygen, it is precipitated from its solvent by the alkalies, earths, and most of the other metals. Its precipitate with ammonia forms a compound, which detonates with great violence, as has been already mentioned under the article Fulminating Powders. Most metals combine with gold, increasing its hardness, but considerably impairing its ductility. For the purposes of coin, Mr. Hatchett considers an alloy of silver and copper in equal parts to be preferred, and copper alone as preferable to silver only: but the gold coins of Great Britain are composed of eleven parts of gold, and one of copper. Gold is mostly found in the metallic state, although generally combined with silver, copper, or iron, or all three. It is found either in separate lumps or visible grains amongst the sands of rivers, in many parts of Europe, and elsewhere. The quantity is for the most part insufficient to pay the expense of separating it; but it is thought to be more universally diffused in sands and earth than any other metal, except iron. Some sands afford gold by simple washing, the heavy metallic particles subsiding first; but when it is imbedded in earths and stones, these substances are first pounded, and then boiled with one tenth of their weight of mercury, together with water. The mercury after a certain time forms an amalgam with the gold, from which it is separated by pressure through leather bags, and subsequent distillation. Gold is seldom used for any purpose in a state of perfect purity. In estimating its fineness, the whole mass spoken of is supposed to weigh 24 carats, of 12 grains each, and the pure gold is called fine. Thus, if gold is said to be 23 carats fine, it is understood that the mass consists of 23 parts of fine gold, and one part of alloy. The principal use of gold is to make coin, trinkets, gold leaf for gilding, and gold wire and thread.

GOLD-BEATERS' SKIN.—The gold-beaters use three kinds of membranes, viz. for the outside cover common parchment, made of sheepskins, is used; for interlaying with the gold, first the smoothest and closest vellum, made of calves' skin; and afterwards the much finer skins of ox-gut, stript off from the large straight gut slit open, curiously prepared for the express purpose, and hence called gold-beaters' skin. According to Dr. Lewis, the preparation of these last is a distinct business, practised only by two or three persons in the kingdom. The general process is supposed to consist in applying them one upon another, by the smooth sides, in a moist state, in which they readily cohere and unite

inseparably, stretching them very carefully on a frame, scraping off the fat and rough matter, so as to leave only the fine exterior membrane of the intestine, at the same time beating them between double leaves of paper, to force out what grease may remain in them, and then drying and pressing them. Notwithstanding the vast extent to which gold is beaten between these skins, and the great tenacity of the skins themselves, they yet sustain continual repetitions of the process for several months, without appearing to extend or grow thinner.

GOLD-BEATING. The gold is prepared for leaves by melting it in a blacklead crucible, with some borax, in a wind furnace; and as soon as it is in perfect fusion, it is poured out into an iron ingot mould, then forged and passed between steel rollers, until they become long ribbons, as thin as writing paper: each of these ribbons is then cut into 150 pieces, and each of these pieces is next forged upon an anvil, till it is about an inch square. These squares, which weigh $6\frac{4}{10}$ grains each, and are about $\frac{1}{160}$ part of an inch thick, are now well annealed, preparatory to the next operation, which consists in interlaying the plates of gold alternately with pieces of very fine vellum, about four inches square, and about twenty vellum leaves are placed on the outsides; the whole is then put into a case of parchment, over which is drawn another similar case, so that the packet is kept tight and close on all sides. It is now laid on a smooth block of marble or metal, of great weight, and the workman begins the beating with a roundfaced hammer, weighing sixteen pounds; the packet is turned occasionally upside down, and beaten till the gold is extended nearly to an equality with the vellum leaves. The packet is then taken to pieces, and each leaf of gold is divided into four, with a steel knife, having a smooth but not very acute edge. The 600 pieces thus produced are interlaid with pieces of animal membrane, (see Goldbeaters' Skin,) from the intestines of the ox, of the same dimensions and in the same manner as the vellum. The beating is continued, but with a hammer weighing only twelve pounds, till the gold is brought to the same dimensions as the interposed membrane. It is now again divided into four, by means of a piece of cane, cut to an edge, the leaves being by this time so thin, that any accidental moisture condensing on an iron blade, would cause them to adhere to it. The 2400 leaves hence resulting are parted into three packets, with interposed membrane as before, and beaten with the finishing hammer, weighing about ten pounds, till they acquire an extent equal to the former. The packets are now taken to pieces, and the gold leaves, by means of a cane instrument and the breath, are laid flat on a cushion of leather, and cut one by one to an even square, by a little square frame, made of cane; they are lastly laid in books of twenty-five leaves each, the paper of which is previously smoothed, and rubbed with red bole, to keep the gold from adhering. By the weight and measure of the best wrought leaf-gold, it is found that one grain is made to cover $56\frac{3}{4}$ square inches; and from the specific gravity of the metal, together with this admeasurement, it follows that the leaf itself is $\frac{1}{282,000}$ part of an inch thick. This, however, is not the limit of the extensibility of the metal; for by computing the surface covered in silver gilt wire, and the quantity of gold used, it is found to be only one-twelfth that of the gold leaf, or $\frac{1}{3,384,000}$ part of an inch thick; nevertheless it is so perfect as to exhibit no cracks when viewed by a microscope.

GOLD THREAD, as it is called, consists of a silk thread covered with gold wire. It is formed by passing gold wire between two rollers of nicely polished steel, set very close together, by which means it is rendered quite flat, but without losing any thing of its polish or gilding, and becomes so exceedingly thin and flexible that it is easily spun upon a silk thread, by means of a hand-wheel, and so wound upon a spool or bobbin.

GOLD WIRE. That which is commonly called gold wire is in fact merely silver wire gilt. The following is the process employed for this purpose. First an ingot of silver of 24 pounds is forged into a cylinder of about an inch in diameter, which is reduced by passing it through eight or ten holes of a large coarse drawing iron, to about three fourths of its former diameter. It is then filed very carefully all over, to remove any dirt from the forge, and after-

wards cut through the middle into two ingots, each about 26 inches long, which are drawn through several new holes to remove any inequalities left by the file, and to render the surface as smooth and equable as possible. The ingot thus far prepared, it is heated in a charcoal fire: then taking some gold leaves, each about four inches square, and weighing 12 grains each, four, eight twelve, or sixteen of them are joined, as the wire is intended to be more or less gilt, and when they are joined so as to form a single leaf, the ingots are rubbed reeking hot with a burnisher, and the leaves applied over the whole surface of the ingot to the number of six over each other, well burnished or rubbed down. When gilt, the ingots are again laid in a charcoal fire, and raised to a certain degree of heat, when they are gone over a second time with the burnisher, both to solder the gold more perfectly, and to finish the polishing. The gilding finished, the ingot is passed through twenty holes of a moderate drawing iron, by which it is reduced to the thickness of the tag of a lace; from this time the ingot loses its name, and commences gold wire. Twenty holes more of a lesser iron leaves it small enough for the least iron, the finest holes of which last, scarcely exceeding the hair of the head, finish the work. Each time that the wire is drawn through a fresh hole it is rubbed afresh with new wax, both to facilitate its passage, and to prevent the silver appearing through it.

GONIOMETER. An instrument for measuring the angles formed by two or more planes, and chiefly, in crystallography, to determine the angles of crystalline substances.

GOUGE. A sort of round hollow chisel, for cutting holes, channels, grooves, &c. in wood or stone.

GRANARY. A storehouse for grain. The construction of this class of buildings has not, we believe, received that attention from the scientific which the importance of it deserves. The best which we have met with in print consists of a plain rectangular building, about twice the height of the distance between the opposite walls, that is 20 feet high by 10 feet in width on each side, and provided with numerous air-holes, declining outwards, to prevent the entrance of rain or snow; from each air-hole to a corresponding one on the opposite side is fixed an inverted angular spout or gutter, which permits the air to pass through unimpeded by the corn lying above it. As many of these gutters are fixed, as there are holes to receive the ends after crossing the building; and the extremities of the holes are covered with wire gauze, to defend them from vermin. The first floor of the granary is divided into a series of hoppers, that empty themselves into one large hopper underneath, provided with a sliding door to regulate the passage of the grain into a sack or other receptacle. At the top of the building is a loft, to which the corn is first hoisted by a tackle or crane, and is discharged over a cross bar into the body of the building, which may be continued until it is filled to the top. Upon drawing off any corn at the bottom, the whole of it is put into motion, and the airing of every part is promoted; the process of airing is however continually going forward through the numerous passages under the inverted gutters, the angles of which, it is said, do not fill up by the lateral pressure of the grain.

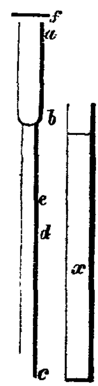
GRANULATION. The method of dividing metallic substances into grains or small particles to facilitate their combination with other substances, and sometimes for the purpose of readily subdividing them by weight. This is done either by pouring the melted metal into water, or by agitating it in a box, until the moment of congelation, at which instant it becomes converted into a powder. Copper is granulated for making brass by pouring it through a perforated ladle into a covered vessel of water, with a movable false bottom. The small shot made of an alloy of lead with arsenic is produced in like manner, by pouring the liquid metal through a perforated colander, and allowing it to fall from a considerable elevation through the air, which causes the drops to assume a spherical shape. See Shot, Solder, &c.

GRAVITY, in Physics, the natural tendency of bodies towards a centre. Terrestrial or particular gravity is that by which bodies descend or tend towards the centre of the earth; the phenomena of which are as follows:—1. All circumterrestrial bodies tend towards a point which is either accurately or nearly

the centre of magnitude of the terraqueous globe. 2. In all places equidistant from the centre of the earth the force of gravity, *cæteris paribus*, is equal. The force of gravity is not equal on all parts of the earth's surface for two reasons; first, because, as the earth is not a sphere, but a spheroid, all parts of its surface are not equidistant from its centre; and secondly, the gravity is different in different latitudes, by reason of variations in the centrifugal force, occasioned by the earth's rotation, the increment of gravity on this account being as the square of the cosine of the latitude. 3. Gravity affects equally all bodies, without regard either to their bulk, figure, or matter; so that in a perfectly unresisting medium, the most compact and the loosest, the greatest and the smallest bodies would descend through an equal space in the same time. The space through which bodies do actually fall in vacuo is $16\frac{1}{2}$ feet in the first second of time in the latitude of London, and for other portions of time either greater or less the spaces are as the squares of the times. 4. Gravity is greatest at the earth's surface, from whence it decreases both upwards and downwards, but not at the same ratio in each direction; the diminution of the force upwards being as the square of the distance from the earth's centre; whilst downwards, the decrease is in the direct ratio of the distance from the centre.

General, or Universal Gravity, is that in consequence of which all the planets tend to one another; and indeed all the bodies and particles of matter in the universe tend to one another.

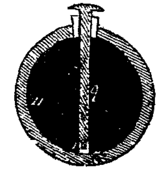
Gravity, specific, is the relative gravity of any body or substance, considered with regard to some other body which is assumed as a standard of comparison, and this standard by universal consent and practice is rain water or distilled water, and by a very fortunate coincidence, at least to English philosophers, it happens that a cubic foot of water weighs 1000 ounces avoirdupoise, and consequently assuming this as the specific gravity of rain water, and comparing all other bodies with this, the same numbers that express the specific gravity of bodies will at the same time denote the weight of a cubic foot of such bodies in avoirdupoise ounces. From the preceding definition may be drawn the following laws of the specific gravity of bodies. 1. In bodies of equal magnitudes, the specific gravities are directly as the densities, or as their weights. 2. In bodies of the same specific gravities, the weights will be as the magnitudes. 3. In bodies of equal weights, the specific gravities are inversely as the magnitudes. 4. The weights of different bodies are to each other in a compound ratio of their magnitudes and specific gravities. 5. When a body is specifically heavier than a fluid it loses as much of its weight when immersed in it as is equal to the weight of a quantity of the same fluid of equal bulk. 6. If the gravity of the fluid be greater than that of the body, then the weight of the quantity of fluid displaced by the part immerged, is equal to the weight of the whole body. The specific gravity of solid bodies is usually determined experimentally by means of the "Hydrostatic Balance," (See BALANCE;) but for ascertaining the specific gravity of liquids, an instrument termed a "Hydrometer" is usually employed. A description of a variety of these instruments will be found under the head HYDROMETER.



The late Professor Leslie invented a new and singularly simple and ingenious method for ascertaining the specific gravity of solids. All substances of this class are more or less porous; and the pores being filled with air which is not expelled when the substance is immersed in water causes their specific gravity when ascertained by the hydrostratic balance to appear less than it really is. In Mr. Leslie's method this source of error is avoided, and some of the results obtained in consequence are extremely curious. The instrument employed consists of a glass tube *a c*, about three feet long, and open at both ends; the wide part *a b* is about four-tenths of an inch in diameter; the part *b c* about two-tenths. The two parts communicate at *b* by an extremely fine slit, which suffers air to pass, but retains sand or powder. The mouth at *a* is ground smooth, and can be shut so as to be air-tight by a small glass plate *f*. The substance whose specific gravity we wish to find is first

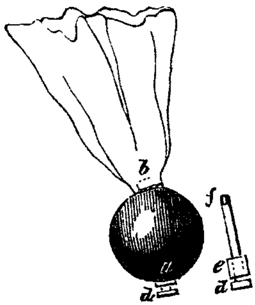
reduced to powder, which is then put into the wide part of the tube *a b*, which may either be filled or not. The tube being then held in a vertical position has the narrow part immersed in mercury, contained in an open vessel *x*, till the metal rises within to the gorge *b*. The lid is then fitted on air-tight at *a*. In this state it is evident there is no air in the tube, except that mixed with the powder in the cavity *a b*. Suppose the barometer at the time to stand at 30 inches, and that the tube is lifted perpendicularly upwards, till the mercury stands in the inside of *b c*, at a point *e* 15 inches, (or one half of 30,) above its surface, in the open vessel; it is evident, then, that the air in the inside of the tube is subjected to a pressure of exactly half an atmosphere: and of course it dilates and fills precisely twice the space it originally occupied. It follows, too, that since the air is dilated to twice its bulk the cavity *a b* contains just half what it did at first; and the cavity *b e* now containing the other half, the quantity of air in each of these parts of the tube is equal. In other words, the quantity of air in *b e* is exactly equal to what is mixed with the powder in *a b*, and occupies precisely the same space which the *whole* occupied *before* its dilatation. Let us now suppose the powder to be taken out, and the same experiment repeated, but with this difference, that the cavity *a b* is filled with air only. It is obvious that the quantity being greater it will, when dilated to double the bulk under a pressure of fifteen inches, occupy a larger space, and the mercury will rise, let us suppose, only to *d*. But the attenuated air in the narrow tube always occupies exactly the space which the whole occupied at ordinary atmospheric pressure; and this space is therefore, in the one case, the cavity *b e*, and in the other *b d*. Hence it follows that the cavity *e d*, which is the difference between these, is equal to the bulk of the solid matter in the sand. Now by marking the number of grains of water held by the narrow tube *b e* on a graduated scale attached to it, we can find at once what is the weight of a quantity of water, equal in bulk to the solid matter in the sand; and by comparing this with the weight of the sand, we have its true specific gravity. Aware that some solid bodies, such as charcoal, hold much condensed air in their pores, and that probably they retain part of this even when reduced to powder, Professor Leslie obviates the chances of error arising from this source by comparing the dilatation which takes place under different degrees of pressure, under 10 inches and 20 for instance, or 7½ and 15. Charcoal, from its porosity, is so light that its specific gravity, as assigned in books, is generally under 0.5 less than half the weight of water, or one seventh the weight of diamond; taken in powder by the above instrument it exceeds that of diamond, is one half greater than that of whinstone, and is, of course, *more than seven times heavier than has usually been supposed.* Mahogany is generally estimated at 1.36; but mahogany sawdust proves by the instrument to be 1.68; wheat flour is 1.46; pounded sugar 1.83; and common salt 2.15; the last agrees very accurately with the common estimate. Writing paper rolled hard by the hand had a specific gravity of 1.78, the solid matter present being less than one third of the space it apparently filled. One of the most remarkable results was with an apparently very light specimen of volcanic ashes, which was found to have a specific gravity of 4.4. These results are, however, given as approximations merely by the first instrument constructed.

GRENADE. A kind of small bomb or shell filled with an explosive composition, and fired by a fusee inserted in the touch-hole. Their principal use is in a close assault, when they are thrown by hand from the tops of ships or ramparts of fortresses, whence they are frequently styled hand grenades. They are usually about three inches in diameter, and weigh about three pounds. Their employment in war is not so general as formerly, owing partly to the uncertain action of the fusee, which renders it difficult to ensure their explosion so as to produce the greatest effect. To obviate this defect, grenades have been invented which are fired by means of a cap containing a priming of percussion powder instead of a lighted fusee. The annexed engraving represents a section of a grenade upon this principle. *a* the shell of cast-iron supposed to be



filled with combustible matter, and having a conical hole into which an iron pin, surrounded by a piece of cork, fits easily; the other extremity of the pin is formed to receive a percussion cap, in which is put a small quantity of percussion powder. The shell being thrown, it will naturally fall on the head of the pin projecting on the outside; the detonating powder is kindled by the blow, and the contents of the shell, as well as the shell itself, are scattered in all directions.

The annexed engraving represents a percussion hand grenade, invented by Capt. Norton of the 34th Regiment. Its construction is precisely the same as that of the foregoing one, but there is in addition a sheet of brown paper, or a piece of common cloth tied to a button, on the outside of the shell, forming a handle to throw it by, and guiding its descent, so that the head of the bolt will infallibly strike the ground, and thereby insure the explosion.



GRINDING. A mechanical process, in which certain effects are produced by the attrition of two surfaces. The process of grinding is of extensive use in various mechanical arts; and great differences exist in the mode of conducting it according to the purposes for which it is employed, which are very varied; thus, in grinding corn, the object is to reduce the grain to an impalpable powder; in grinding lenses, it is to give them a certain figure and polish; cocks and valves are ground into their seats to promote intimate contact; colours are ground to promote the intimate mixture of the colouring matter with the oil; and cutlery and tools are ground, to impart to them a sharp edge. The latter operation, as is well known, is performed by applying the articles to be ground to the periphery of a cylindrical stone of a rough, gritty texture, revolving with great rapidity; and to reduce as much as possible the heat caused by the friction of the two surfaces, the stone is mounted over a trough containing water. Some curious experiments are detailed in Nicholson's Journal upon this point, from which it appears that tallow is much more effective than water in keeping the temperature low; for in trying to grind down the teeth of a file with the grindstone immersed in water, the file soon became too hot to hold, and the teeth were scarcely touched, but by applying a tallow candle to a dry grindstone as it revolved, so as to give an even coating of tallow, he was enabled to grind down the teeth rapidly, and the temperature of the file was scarcely raised until the tallow became melted. This effect Mr. Nicholson attributes to the heat absorbed or rendered latent in bringing a solid substance into a fluid state.

GRINDSTONE. A flat circular stone, mounted on a spindle, and turned by a winch handle, used for the purpose of grinding edge tools. In districts where cutlery and edge tools are manufactured, great numbers of these stones are used in one building, called a blade mill or grind mill. The stone suited to form grindstones is composed of a coarse species of sandstone. The finer sorts of grindstones, and what are called whitening or polishing stones, by the Sheffield cutlers, are from different rocks in the upper part of the great Derbyshire Coal Series; others are from Staffordshire, Warwickshire, &c.

GUITAR. A musical instrument with five double rows of strings, of which those that are bass are in the middle.

GUM. A vegetable juice, or thick, transparent, tasteless fluid, which sometimes exudes from certain species of trees. It is very adhesive, and gradually hardens without losing its transparency; but easily softens again when moistened with water. The gum most commonly used is that which is procured from different species of the Acacia in Egypt, Arabia, &c.; it is known by the name of gum arabic. Gum likewise exudes abundantly from the common wild cherry tree of this country: it exists also in various plants in the state of mucilage, especially in the roots and leaves. It is most abundant in bulbous roots; and of these, the hyacinth affords the largest quantity. Gum readily dissolves

in water, and the solution, which is thick and adhesive, is known by the name of mucilage. It is also soluble in the vegetable acids, but is decomposed by the sulphuric, nitric, and muriatic acids. It is insoluble in alcohol and ether.

GUN. A fire-arm or weapon chiefly composed of a barrel or long tube, from which shot and other missiles are discharged by means of inflamed gunpowder; ignition being effected by the percussion of flint and steel, or that of detonating powder, through the instrumentality of a piece of mechanism called the lock, which is fixed to the handle or stock, and in connexion with the lower extremity of the barrel, where the charge is deposited. The word gun, however, is indiscriminately applied to almost every species of fire-arm, and is usually divided into two classes, namely, great guns, and small arms. The former include cannon, artillery, and various species of ordnance, that are moved on wheels, pivots, trucks, and slides, which are described under their separate heads; the latter class, which embraces muskets, blunderbusses, carbines, fowling-pieces, and pistols, being such as are manufactured by gun-smiths, we propose to describe in this place.

The principal parts of a gun are the barrel, the lock, and the stock. The following are the requisite properties of the barrel:—first, lightness, that it may incommode the person who carries it as little as possible; secondly, sufficient strength, and other properties requisite to prevent its bursting by a discharge; thirdly, it should be constructed in such a manner as not to recoil with violence; and fourthly, it should be of sufficient length to carry the shot to as great a distance as the force of the powder employed is capable of doing. The best barrels in this country are formed of stubs, as they are called, or old pieces of horse-shoe nails. About twenty-eight pounds of these are requisite to form a single musket barrel. The method of manufacturing them from this material is as follows:—a hoop of about an inch broad, and six or seven inches diameter, is placed in a perpendicular position, and the stubs, previously well cleaned, piled up in it with their heads outermost on each side, till the hoop is quite filled and wedged tight with them. The whole then resembles a rough circular cake of iron, which being heated to a white heat, and then strongly hammered, unite into one solid lump. The hoop is now removed, and the heatings and hammerings repeated till the iron is rendered very tough and close in the grain, when it is drawn out into pieces of about twenty-four inches in length, half an inch or more in breadth, and half an inch in thickness. Four of the pieces, prepared as has been described, are required for one barrel; but in the ordinary way, a single bar of the best soft iron is employed. The workmen begin with hammering out this into the form of a flat ruler, having its length and breadth proportioned to the dimensions of the intended barrel. By repeated heating and hammering, this plate is turned round a tempered iron rod called a mandril, the diameter of which is considerably smaller than the intended bore of the barrel. One of the edges of the plate being laid over the other about half an inch, the whole is heated and welded by two or three inches at a time, hammering it briskly, but with moderate strokes, upon an anvil, which has a number of semicircular furrows in it, adapted to the barrels of different sizes. Every time the barrel is withdrawn from the fire the workman strikes it gently against the anvil once or twice in a horizontal direction. By this operation the particles of the metal are more perfectly consolidated, and every appearance of a seam in the barrel is obliterated. The mandril being then again introduced into the cavity of the barrel, the latter is very strongly hammered upon it in one of the semicircular hollows of the anvil by small portions at a time, the heatings and hammerings being repeated until the whole barrel has undergone the operation, and its parts rendered as perfectly continuous as if they had been formed out of a solid piece. To effect this completely three welding heats are necessary when the very best iron is made use of, and a greater number for the coarser kinds.

The next operation in forming the barrels is the boring of them, which is usually done in the following manner:—Two beams of oak, each about six inches in diameter, and six or seven feet long, are placed horizontally, and parallel to one another, having each of their extremities mortised upon a strong

upright piece about three feet high, and firmly fixed; a space of three or four inches is left between the horizontal pieces, in which a piece of wood is made to slide by having at either end a tenon let into a groove, which runs on the inside of each beam throughout its whole length. Through this sliding piece a strong pin or bolt of iron is driven or screwed in a perpendicular direction, having at its upper end a round hole large enough to admit the breech of the barrel, which is secured in it by means of a piece of iron that serves as a wedge, and a vertical screw passing through the upper part of the hole. A chain is fastened to a staple on one side of the sliding piece, which runs between the two horizontal beams, and passing over a pulley at one end of the machine, has a weight hooked on to it; an upright piece of timber is fixed above this pulley and between the ends of the beams, having its upper end perforated by the axis of an iron crank furnished with a square socket, the other axis being supported by the wall, or by a strong post, and loaded with a heavy wheel of cast-iron to give it force. The axes of this crank are in a line with the hole in the bolt already mentioned. The borer being then fixed into the socket of the crank, has its other end, previously well oiled, introduced into the barrel, whose breech part is made fast in the hole of the bolt; the chain is then carried over the pulley, and the weight hooked on; the crank being then turned with the hand, the barrel advances as the borer cuts its way till it has passed through the whole length. The boring bit consists of an iron rod somewhat longer than the barrel, one end of which fits the socket of the crank; the other is adapted to a cylindrical piece of tempered steel, about an inch and a half in length, having its surface cut after the manner of a perpetual screw, with five or six threads, the obliquity of which is very small; the breadth of the furrows is the same with that of the threads, and their depth sufficient to let the metal cut by the threads pass through them easily; thus the bit gets a strong hold of the metal, and the threads being sharp at the edges, scoop out and remove all the inequalities and roughness from the inside of the barrel, and render the cavity smooth and equal throughout. A number of bits, each a little larger than the former, are afterwards successively passed through the barrel in the same way, until the bore has acquired the magnitude intended. By this operation the barrel is very much heated, especially the first time the borer is passed through it, by which means it is apt to warp: to prevent this in some measure, the barrel is covered with a cloth kept constantly wetted, which not only preserves the barrel from an excess of heat, but likewise preserves the temper of the bit from being destroyed. The equality of the bore is of the utmost consequence to the perfection of a barrel, insomuch that the greatest possible accuracy in every other respect will not make amends for any deficiency in this. The method used by gunsmiths to ascertain this is by a cylindrical plug of tempered steel highly polished, about an inch in length, and fitting the bore exactly; this is screwed upon the end of an iron rod, and introduced into the cavity of the barrel, where it is moved backwards and forwards; and the places where it passes with difficulty being marked, the boring bit is repeatedly passed until it moves with equal ease through every part. In forming the breech, a tap is introduced into the barrel, and worked from left to right, and back again, until it has marked out the first four threads of the screw; another less conical tap is introduced; and when this has carried the impression of the screw as far as it is intended to go, a third one, nearly cylindrical, is made use of, scarcely differing from the plug of the breech intended to fill the screw thus formed in the barrel; the plug itself has its screw formed by means of a screw plate of tempered steel, with several female screws corresponding with the taps employed for forming that in the barrel. Seven or eight threads make a sufficient length for a plug; they ought to be neat and sharp, so as completely to fill the turns made in the barrel by the tap. The breech plug is then to be case-hardened, or to have its surface converted into steel by covering it with shavings of horn, or the parings of the hoofs of horses, and keeping it for some time red hot, after which it is plunged in cold water.

The above is the usual method of making the common barrels, especially for fowling pieces; but there are some other methods of manufacture by which

they are thought to be considerably improved. One kind of these are called twisted barrels, and by the English workmen are formed out of the plates made of stubs, as above described. Four of these, of the size already mentioned, are requisite to make one barrel; one of them heated red hot for five or six inches, is turned like a cork-screw by means of the hammer and anvil, the remaining parts being treated successively in the same manner until the whole is turned into a spiral forming a tube, the diameter of which corresponds with the bore of the intended barrel. Four are generally sufficient to form a barrel of the ordinary length, that is from 32 to 38 inches; and the two which form the breech or strongest part, called the reinforced part, are considerably thicker than those which form the muzzle or fore part of the barrel: one of these tubes is then welded to a part of the old barrel to serve as a handle; after which the turns of the spiral are united by heating the tube two or three inches at a time to a bright white heat, and striking the end of it several times against the anvil in a horizontal direction with considerable force, which is called jumping the barrel; and the heats given for this purpose are called jumping heats. The next step is to introduce a mandril into the cavity, and to hammer the heated portion lightly, in order to flatten the ridges or burrs raised by the jumping at the place where the spirals are joined. As soon as one piece is jumped throughout its whole length, another is welded to it and treated in the same manner until the four pieces are united, when the part of the old barrel is cut off as being no longer of any use. The welding is repeated three times at least, and is performed exactly in the same manner as directed for plain barrels; and the piece may afterwards be finished according to the directions already given. The advantages of twisted barrels are, after all, somewhat problematical, where there is so much of welding; and that in a spiral form, the welding is more likely to be done in a careless manner, or with some imperfection in some part, than when it is a plain, is an obvious business; nor have we observed that twisted barrels are less liable to burst than plain ones, where the latter have been well and carefully forged. The manufacture of rifle barrels, in their first formation, is exactly similar to that of other barrels, except that their external form is generally octagonal: instead of being smooth on the inside, like the common pieces, they are formed with a number of spiral channels resembling those of a screw, except only that the threads or rifles are less deflected, making only one turn, or a little more, in the whole length of the piece. This construction of the barrel is employed for correcting the irregularity in the flight of balls from smooth barrels. The rifle barrels which have been made in England, where they are not very common, are contrived to be charged at the breech, the piece being for this purpose made larger there than in any other part; the powder and bullet are put in through the side of the barrel by an opening, which, when the piece is loaded, is filled up with a screw; by this means, when the piece is fired, the bullet is forced through the rifles, and is projected with greater truth. The principal imperfections to which gun barrels are liable are the chink, crack, and flaw; the first is a small rent in the direction of the length of the barrel; the second across it; and the third is a kind of scale or small plate adhering to the barrel by a narrow base, from which it spreads out like the head of a nail from its shank, and, when separated, leaves a pit or hollow in the metal. The chink or flaw are of much worse consequence than the crack in fire-arms, the force of the powder being exerted more upon the circumference than the length of the barrel. The flaw is much more frequent than the chink, the latter scarcely ever occurring but in plain barrels formed out of a single plate of iron, and then only when the metal is deficient in quality: when flaws happen on the outside they are of no great consequence; but in the inside they are apt to lodge moisture and foulness, which corrode the iron, and thus the cavity enlarges continually till the piece bursts. This accident, however, may arise from many other causes besides the defect of the barrel itself; the best pieces will burst when the ball is not sufficiently rammed home, so that a space is left behind it and the powder; a very small windage or passage for the inflamed powder between the sides of the barrel and ball will be sufficient to prevent the accident; but if

the ball has been forcibly driven down with an iron ramrod, so as to fill up the cavity of the barrel very exactly, the piece will almost certainly burst, if only a very small place is left between it and the powder; and the greater the space is, the more certainly does the event take place. A piece will undoubtedly burst from having its mouth stopped up with earth or snow; which accident sometimes happens to sportsmen in leaping a ditch, in which they have assisted themselves with their fowling-piece, putting the mouth of it to the ground; and when this did not happen, it is only to be accounted for from the stoppage being extremely slight. For the same reason, a musket will certainly burst if it is fired with the muzzle immersed only a very little way in water; it will also burst from an overcharge; but when such an accident happens in other circumstances, it is most probably to be attributed to a defect in the workmanship, or in the iron itself. These defects are principally an imperfection in the welding, a deep flaw having taken place, or an inequality in the bore; which last is the most common of any, especially in the low priced barrels. The reason of a barrel's bursting from the inequality of the bore is, that the elastic fluid set loose by the inflammation of the powder, and endeavouring to expand itself in every direction, being repelled by the stronger parts, acts with additional force against the weaker ones, and frequently bursts through them, which it would not have done had the sides been equally thick and strong throughout. With regard to defects arising from the bad quality of the iron, it is impossible to say any thing certain, as the choice of the materials depends entirely on the gunsmith. The only way to be assured of having a barrel made of proper metal, is to purchase it of a manufacturer of known reputation, and to give a liberal price for the piece.

The recoil of a gun becomes an object of importance only when it is very great, for every piece recoils in some degree when it is discharged. The most frequent cause of an excessive recoil is an inequality in the bore of the barrel; and by this it will be occasioned even when the inequality is too small to be perceived by the eye. The explanation of this upon mechanical principles, indeed, is not very obvious; for as it is an invariable law that action and reaction are equal to one another, we should be apt to suppose that every time a piece is discharged it should recoil with the whole difference between the velocity of the bullet and that of the inflamed powder. The cause to which too great a recoil in muskets has been usually attributed, is the placing of the touch-hole at some distance from the breech-plug, so that the powder is fired about the middle, or towards its fore part, rather than at its base; to avoid this, a groove or channel is often made in the breech-plug as deep as the second or third turn of the screw, the touch-hole opening into this channel, and thus firing the powder at its very lowest part. It appears, however, from a number of experiments made upon this subject by M. Le Clere, that it made very little difference with regard to the recoil, whether the touch-hole was close to the breech, or an inch distant from it. The only circumstance to be attended to with respect to its situation, therefore, is, that it be not quite close to the breech-plug, as in such a case it is found to be more apt to be choked up than when placed about a quarter of an inch from it. It was formerly supposed, that the longer gun barrels were made the greater would be the distance to which they carried the shot, and that without any limitation. This opinion continued to prevail till near a century ago, when it was first proposed as a doubt whether long barrels carried further than short ones. Mr. Robins informs us, that "if a musket barrel of the common length and bore is fired with a leaden bullet and half its weight of powder, and if the same barrel is afterwards shortened one-half, and fired with the same charge, the velocity of the bullet in this shortened barrel will be about one-sixth less than what it was when the barrel was entire; and if, instead of shortening the barrel, it is increased to twice its usual length, when it will be near eight feet long, the velocity of the bullet will not be augmented more than one-eighth part; and the greater the length of the barrel is in proportion to the diameter of the bullet, and the smaller the quantity of powder, the more inconsiderable will these alterations of velocity be." From these considerations it appears that the advantages gained by long

barrels are by no means equivalent to the disadvantages arising from the weight and incumbrance of using them; and from a multitude of experiments, it is now apparent that any one may choose what length he pleases without any sensible detriment to the range of the piece. The most approved lengths are from 30 to 36 inches. An opinion has generally prevailed among sportsmen, that by some unknown manœuvre the gunsmith is able to make a piece loaded with small shot, throw the contents so close together, that even at the distance of 40 or 50 paces the whole will be confined within the breadth of a hat. From such experiments as have been made on this subject, however, it appears that the closeness or wideness with which a piece throws its shot, is liable to innumerable variations from causes which no skill in the gunsmith can possibly reach. So variable are these causes, that there is no possibility of making the same piece throw its shot equally close twice successively. In general, however, the closer the wadding is the better disposed the shot seems to be to fall within a small compass. In firing with small shot a curious circumstance sometimes occurs, viz. that the grains, instead of being equally distributed over the space they strike, are thrown in clusters of 10, 12, 15, or more; whilst several considerable spaces are left without a grain in them. Sometimes one-third or one-half of the charge will be collected into a cluster of this kind; nay, sometimes, though much more rarely, the whole charge will be collected into one mass, so as to pierce a board near an inch thick at the distance of 40 or 45 paces. Small barrels are said to be more liable to this clustering than large ones; and M. de Marolles informs us that this is especially the case when the barrels are new, and likewise when they are fresh washed; though he acknowledges that it did not always happen with the barrels he employed, even after they were washed. It is probable, therefore, that the closeness of the shot depends on some circumstance relative to the wadding rather than to the mechanism of the barrel.

The lock of the gun, which comes next to be considered, was originally only a cleft piece of iron, moving on a pin fixed in a stock. To this succeeded the wheel lock, so called from a small wheel of solid steel, which being let off by a spring, by its rapid evolutions elicited fire from the flint, and ignited the priming. This was superseded by the snaplance, in which a motion was given to the cock which held the flint, and a movable plate of steel called the frizel, or hammer, was placed vertically above the pan to receive it. A great many improvements in gun locks have been made during the last twenty or thirty years, which have contributed to render this part of the gun admirably efficient. Our space will not permit us to enter into details; we therefore refer the reader to the periodical works descriptive of patent inventions. The important requisites in a gun lock are, that the action of the cock be as rapid as possible, and that it should be so placed, that on uncovering the pan the flint may point into the centre of the priming, and as near to it as possible, without touching it; the main spring should have a smooth and active motion; the hammer spring should be light, and should give a slight resistance to the cock on its striking the steel, which ought to move on a roller.

The stocks of guns have assumed a great variety of forms. Sportsmen's guns, till within these thirty years, were made very crooked in the stock, and no regard was then paid to the balance of the piece; since that period straight stocks have been universally adopted, and the length of the stock has been accommodated to the stature of the person for whom it is made.

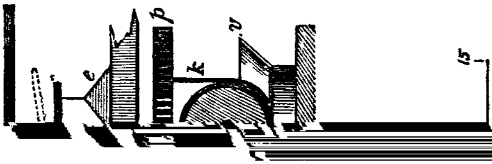
GUNNERY. The art of employing artillery and other fire-arms against an enemy with the best effect, including every thing that is necessary to a complete knowledge of the most approved methods of mounting, transporting, charging, directing, discharging, &c. the above. It includes also a knowledge of pyrotechny, the theory, force, and effect of gunpowder, the proportions of powder and ball required to produce a proposed effect; and rules for computing the range of the projectile, the elevation of the piece, &c.

GUNPOWDER. The origin of the invention of gunpowder is a question upon which the learned are by no means agreed; some attributing it to Schwartz, a German monk, in 1320, others to Roger Bacon, who lived nearly

a hundred years prior to that date; whilst other writers again contend, and with every appearance of probability, that the invention had its rise in the East, and that it has been known to the Indians and Chinese for thousands of years. The most improved proportions for the composition of gunpowder are 75 parts by weight of nitre, to 16 of charcoal, and 9 of sulphur, which being separately reduced to a fine powder, are intimately blended together with a small quantity of water. This operation was formerly performed in wooden mortars, with wooden pestles; in the large way by means of a mill, wherein the mortars were disposed in rows, and in each of the mortars a pestle was moved by the arbor of a water wheel. The heat, however, produced by the blows of the pestle, occasioned such frequent explosions, that an Act of Parliament was passed in the 12th of Geo. III. prohibiting their use, and limiting the licenses to mills similar in principle to the one which we shall describe towards the close of this article. The mixture is, from time to time, moistened with water which serves to prevent its being dissipated in the pulverulent form, and likewise obviates the danger of explosion. When the process of blending the materials together in this manner is complete, (which requires several hours,) the gunpowder is in fact made, and only requires to be dried, to render it fit for use. The granulation of gunpowder is effected by placing the mass, while in the form of a stiff paste, in a wire sieve, covering it with a board, and agitating the whole; by the pressure of the board, it is thus cut into small grains or parts. The powder is smoothed or glazed, as it is called, for small arms, by the following operation: a hollow cylinder or cask is mounted on an axis, and turned by means of a water-wheel or other power; this cask is half filled with powder, and turned for six hours, and thus by the mutual friction of the grains of powder, it is smoothed or glazed. The fine mealy part thus separated from the rest is again granulated. The granulation causes it to take fire more readily, as the inflammation is more speedily propagated through the interstices of the grains. The variations in the strength of different samples of gunpowder are generally owing to the more or less minute division and intimate mixture of the parts; the reason of this may be easily deduced from the consideration, that nitre does not detonate until in contact with inflammable matter, consequently the whole detonation will be the more speedy the more numerous the points of contact. For this reason also the ingredients should be very pure, as the mixture of any foreign matter not only diminishes the quantity of effective ingredients, but prevents their contact by its interposition. The elastic product obtained by the detonation of gunpowder was found by Berthollet to consist of two parts of nitrogen gas, and one part of carbonic acid gas. The sudden extrication and expansion of these gases are the cause of the effects of gunpowder.

We shall now proceed to describe an improved gunpowder mill invented by Mr. James Monk, the manager at the gunpowder mills of Messrs. Burton, Children, and Burton, near Tunbridge. Some few years ago a model and description of it was presented to the Society of Arts, who voted to Mr. Monk their silver medal and twenty guineas, as a mark of their sense of its merits. *a a Fig.* 1, on the following page, is a compound lever, formed of two iron bars, the extremities of which terminate above the bedstones of the pair of mills, A B; these levers are connected at their other extremities by a bolt at *b*, forming a joint, and permitting the levers to move so as to form a very obtuse angle, when a power from below upwards is applied to either of the ends of the levers *a a* as shown by the dotted lines. *c c* are two oblong holes in the lever bars, through which two screws are put, which, being screwed into the two uprights, constitute the two fixed fulcrums of the levers; *d d* are two uprights, with an eye or loop in each to receive and steady the ends of the lever, which are made long enough to allow the bars to take the position indicated by the dotted lines; *e e* are two blowers, made of thin sheet iron, in the form of hollow three-sided pyramids, and are suspended by two iron rods to the ends of the levers *a a*. These blowers are placed as near as possible to the tops of the upright stone shafts, and as close to the wheels as the timber will allow; *f f* are two copper chains attached by one end to the lever bars, and by the other supporting two copper valves, which

are not seen in *Fig.* 1, being inside the tubs; but one of them is shown at *g* in the section of a tub, *Fig.* 2. *h h* are two oval tubs capable of holding six gallons of water, and having a circular hole at the bottom; surrounding this hole is a grooved block having a cylindrical channel all round it, into which the bottom edges of the cylindrical valves fit, shown in section at *Fig.* 2. *i i* are two small spring catches fastened to the two uprights. The lever bars are laid on the top of these catches, so that when the ends of the levers rise, that part



mercury, and the water in both tubs will pour down on their respective bedstones, extinguishing in one the inflamed powder, and in the other preventing it from taking fire. In a certain stage of the grinding the materials are apt to clot and adhere to the runners; parts of the bedstones are thus left bare, and the runner and bedstone coming in contact, an accidental spark may be elicited, and an explosion ensue. To prevent this most usual cause of accidents, Mr. Monk fixes to the axles of the wheel a scraper formed of a curved piece of wood *k* shod with copper, which, being placed behind and almost touching each of the runners, scrapes off the powder as it collects, and thus keeps each of the bedstones always covered. *l* is the greater water-wheel, which gives motion to the rest; *m m* are two vertical beveled wheels, fixed on the axis of the great wheel; *n n* two horizontal bevel wheels working in *m m*, and turning the vertical shafts, upon the upper part of which are also fixed two horizontal wheels *o o*, which drive the wheels *p p*. To the shafts of these latter wheels are fixed the runners *q q*, which traverse on the bedstones *u u; v v* are the curbs surrounding the bedstone to keep the powder from falling off. The mill A presents a view, and the mill B a section of the bedstone and curb. *Fig.* 2 shows the position of the apparatus after an explosion has taken place; the valve being raised up out of the channel, and the water pouring down on the bedstone.

GUNWALE, or GUNNEL, is the piece of timber in a ship which reaches on either side from the half-deck to the forecastle, being the uppermost bend, which finishes the upper works of the hull in that part.

GYPSUM. A substance which is very abundant in nature, and is now denominated, according to the new chemical arrangement, the sulphate of lime. It forms immense strata, composing entire mountains; it is found in almost every soil, either in greater or less quantities; it is contained in the waters of the ocean, and in almost all river and spring water. In these its presence is the cause of the quality termed hardness, which may be known by the water being incapable of forming a solution of soap, the sulphuric acid seizing on the alkali of the soap, and the oil forming a compound with the lime. Sulphate of lime is insipid, white, and soft to the touch; water will not hold a five-hundredth part of it in solution. Exposed to heat it appears to effervesce, which phenomenon is caused by the expulsion of water; it becomes opaque, and falls into powder. This powder, when its water has been driven off by the application of a red heat, absorbs water rapidly, so that if it be formed into a paste with water, it dries in a few minutes. In this state it is called plaster of Paris, and is employed for forming casts, and for a variety of purposes in the art of statuary.

H.

HACKLE. An instrument or tool used in *hackling* or straightening the fibres of flax. It consists of several rows of long sharp iron teeth, fixed in a piece of wood, and placed with their points upwards before the workman, who strikes the flax, which he holds in his hand, upon the teeth of the hackle, drawing it quickly through them. According to the quality of the flax, or the purpose for which it is designed, the workmen use a hackle with finer, coarser, or wider teeth; but generally using a coarse one first and a finer afterwards. See Flax.

HAEMATITES. An ore of iron.

HAIR. Slender filaments issuing out of the pores of the skins of animals, and serving most of them as a covering. All hair appears round; but the microscope shows them to be of various shapes, as square, triangular, hexangular, &c. The human hair forms a considerable article of commerce, principally for the manufacture of perukes. The hair of northern countries is preferred on account of its greater strength and length. Hair is sometimes bleached on the grass like linen, after previous washing and steeping in a bleaching liquid; it may then be dyed of any colour. When it does not curl naturally, it is made to do so by first boiling it and then baking it in an oven.

M. Vanquelin, who investigated the chemical constituents of hair, found that red hair differs from black only in containing a red oil instead of a blackish green oil; and that white hair differs from both these only in the oil being nearly colourless, and in containing phosphate of magnesia, which is not found in them. Hair is usually distinguished into various kinds; the stiffest and strongest, such as those on the back of swine, are called bristles. The soft and pliable, like that on sheep, is called wool; and the finest of all is called down. Hair is also woven into cloth (of which it forms only the weft) for covering the seats of chairs and sofas, besides other purposes.

HAIR POWDER. The starch of wheat finely pulverized, and variously scented.

HALBERT, or Halberd. A kind of spear having a staff about six feet long, much in use formerly, but now chiefly confined to the serjeants of foot.

HAM. The leg or thigh of pork, dried, seasoned, and prepared to make it keep, and give it an agreeable flavour. Westphalia hams, which are most esteemed, are prepared by salting them with saltpetre, pressing them for eight or ten days, then steeping them in juniper water, and drying them in the smoke of juniper wood. The curing of hams in this country is, first, by common salting, to extract the blood; the hams are then wiped dry, and afterwards salted in a mixture of common salt, saltpetre, and brown sugar; in this pickle they remain for about three weeks, and are afterwards dried in a chimney, or on the great scale, in a stove constructed for the purpose.

HAMMER. A well-known instrument used by workmen, of which there are numerous varieties, adapted to the peculiar work they are designed for. The general form is that of an iron head, having a handle at right angles to it. The class called rivetting hammers have the handle fixed to them by passing it through a hole in the head, where it is made to fit or be wedged firmly; the face is formed of steel, as well as the rivetting end (called the pans), which are welded to the iron. These hammers are used by carpenters, smiths, engineers, and numerous artisans, and vary in some peculiarities of form; and as respects weight, from an ounce to many pounds, or that of a sledge-hammer. Of the last mentioned there are various sorts and sizes; also of hand or up-hand hammers, which are a medium size between the two before mentioned, and are so called from the capacity of the w rkman to use them with one hand. A variety of hammers having two claws, called claw hammers and Kent hammers, are extensively used by carpenters and other trades, as the claw, together with its handle, forms a powerful lever for drawing nails and other purposes requiring great force. The late Mr. Walby, of Islington (who is succeeded by his son), distinguished himself by the construction of a very ingenious apparatus, by which he worked a hammer at the rate of 800 blows per minute, in the manufacture of a very superior quality of bricklayers' trowels. For the construction and mode of working those prodigious hammers, called *tilt-hammers*, see the article Iron.

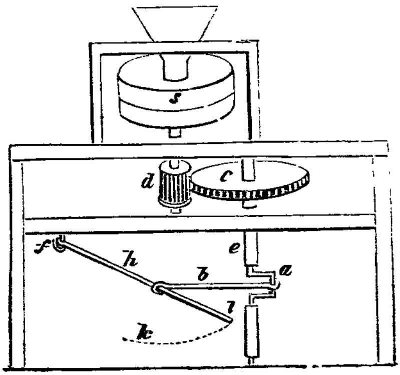
HAMMOCK. A suspended bed, usually consisting of a piece of sacking about three feet wide and six feet long, gathered or drawn together at the two ends, and suspended from only one point at each end. They are chiefly used on ship-board, and between decks; in warm countries they are likewise employed for persons to sleep in the open air, by suspending them to posts or to trees.

HAND. A measure of four inches, or that of the clenched fist.

HANDCUFFS. Two circular pieces of iron, provided with hinge joints to open and shut them by, and a lock to secure them when together; employed to secure prisoners or malefactors.

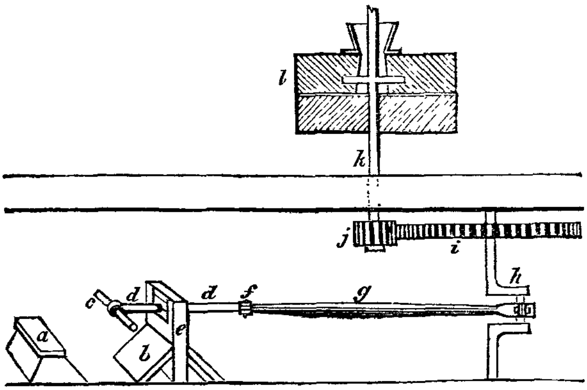
HAND-MILLS. This term does not properly apply to any specific kind of mill, but to all that are worked by hand, such as those employed in the domestic offices of grinding coffee, pepper, &c. There are, however, mills of a larger description, which are also worked by hand for grinding malt, wheat, and other substances; and in the houses for the reception and employment of the poor, it is not uncommon to employ the united force of a great number of persons in grinding corn and dressing the meal for the establishment; and the

mode of applying their power is almost uniformly that of turning a winch or crank, made of sufficient length for that purpose. The winch undoubtedly possesses the advantages of great simplicity and convenience; and it has probably, on those accounts, been generally adopted. It has, however, been the opinion of many eminent mechanics, that the most effective mode of employing human force, is the action of rowing a boat. On this point the ingenious Dr. Desaguliers observed, that more muscles are employed at once for overcoming the resistance, than in any other position; and that the weight of his body assists in the act of pulling backwards. The following mechanical arrangement for carrying the principle into effect is given in Brockler's *Theatrum Machinarum.* The vertical shaft *e* carries a large toothed wheel *c;* the latter being intended to operate partly as a regulating fly. Upon the crank *a* hangs one end of an iron *b*, the other end of which hangs upon the lever *h l*, the motion being perfectly free at both ends of the bar *l*. One end of the lever *h l* hangs upon the fixed hook *f*, about which, as a centre of motion, it turns; then, while a man, by pulling at the lever *h l*, moves the extremity *l* from *l* to *k*, the bar *b*, acting upon the crank *a*, gives to the wheel *c* half a rotation; and the momentum it has acquired will carry them on, the man at the lever suffering it to turn back from *k* to *l*, while the other half of the rotation of the wheel is completed. In like manner another sufficient pull at the lever *h l* gives another rotation to the wheel *c*, and so on at pleasure. The wheel *c* turns by its teeth the trundle *d*, the spindle of which carries the upper mill-stone. If the number of the teeth in the wheel *c* be six times the number of the cogs in the trundle *d*, then the labourer, by making ten pulls at the lever *h l* in a minute, will give sixty revolutions to the upper mill-stone in the same space of time.



We have given insertion to this "rowing-mill," as it is termed, on account of the great praise bestowed upon it by succeeding eminent writers; but we cannot regard it as a very judicious mode of carrying the principle into effect, for two reasons;—*First*, the large wheel making but ten revolutions per minute, will not become a very efficient regulator of power; if fixed upon the first motion, it must be made inconveniently large or weighty to collect the requisite force to be useful. If a fly-wheel be used at all, it should be put on the axis of the trundle *d*, where the velocity is six times greater; the increased momentum it would here acquire, would far more than compensate for the small loss of effect by its removal farther from the motive force. But we doubt much the use of a fly-wheel at all in the present case, because a heavy mill-stone is put into operation; and that is, in effect, a far more efficacious fly-wheel than the above described. *Second*, because we think the inventor has imitated the *defects* as well as the advantages of the rowing action. In this mill the workman is supposed to pull the lever *h l* through the arc of a circle *l k;* and this indirect action, it will be noticed, is performed in a horizontal plane, by which a contortion of the man's body results that must be unfavourable to his health, and the most efficient exercise of his strength. To avoid these defects in the rowing-mill, we propose the following simplified, and, we trust, improved arrangement. *a* represents a seat for one or two men; *b* a board to press their feet against in pulling back by the cross handle *c*, which is connected to a rod *d* that slides *straight* through brasses fixed in a standard *e;* at *f* is a hinge joint, which permits the connecting rod *g* to vibrate with the revolution of the crank *h*, whose axis actuates the wheel *i*, the pinion or

trundle j, on the axis k of which, is fixed the runner-stone l, serving also the office of a fly-wheel. In applying the labour of more men to an apparatus of this kind, there would be some advantage in placing them opposite to each other so that a pull should be made each way. For this purpose the rod $d\,d$



might be lengthened, another seat be placed on the other side of the standard e, and another cross handle between d and f; the men sitting here on each side of the rod d.

Having now explained what is deemed the most advantageous application of manual labour to mills, and the undefined nature of the term which heads this article, we refer the reader for more information on the subject, and that of mills generally, to the article MILL.

HANDSPIKE. A name given to a simple lever consisting of a bar of wood or iron, chiefly used on board ship for heaving round the windlass.

HARBOUR. A place where ships may lie at anchor, secure from storms. The principal qualities of a good harbour are, sufficient depth of water to float the largest ships, and sufficient breadth and depth for them to enter with facility, and without danger of foundering. The ground should be firm, and free from rocks. It is desirable that they be surrounded by lofty hills or mountains, to screen them from high winds, and the better if so far inland as to derive therefrom increased security against being bombarded by an enemy at sea. They should also be provided with a good light-house to direct ships at night, and with numerous buoys, posts, moorings, &c. Harbours are sometimes formed artificially, either wholly or partially, by the building of moles, breakwaters, piers, and sometimes by large floating masses of timber, which rise and fall with the tide. See the articles BUOY, BREAKWATER, and CAISSON.

HARDNESS. The resistance opposed by a body to the separation of its particles. This property depends on the force of cohesion, or on that which chemists call affinity, joined to the arrangement of the particles to their figure, and other circumstances. The differences between hard bodies, such as are soft, and such as are elastic, have been thus defined. The soft body yields to pressure without spontaneously returning to its previous form on taking off the pressure; the elastic body returns to its original form upon removing the force applied; while that which is strictly hard breaks asunder when overcome by the force brought against it. It is, however, justly doubted whether there is any body in nature that is perfectly hard, perfectly soft, or perfectly elastic; for all bodies seem to possess these three qualities, though in proportions indefinitely various.

HARDENING and CASE-HARDENING. See IRON and STEEL.

HARMONICA. The name given to a musical instrument invented by

Dr. Franklin, in which the tones are produced by friction against the edges of a series of glasses. The glasses are blown as near as possible into the form of hemispheres, having each an open neck or socket in the middle. The thickness of the glass near the brim is about one-tenth of an inch, but thicker as it comes nearer the neck, which, in the largest glasses, is about an inch deep, and an inch and a half wide within; these dimensions lessening as the glasses themselves diminish in size, except that the neck of the smallest ought not to be shorter than half an inch. The largest glass is nine inches in diameter, and the smallest three inches. Between these there are twenty-three different sizes, differing from each other a quarter of an inch in diameter. The glasses being chosen, and every one marked with a diamond the note for which it is intended, they are to be tuned by diminishing the thickness of those that are too sharp. This is done by grinding them round from the neck towards the brim, the breadth of one or two inches, as may be required, often trying the glass by a well-tuned piano-forte or harpsichord. The largest glass in the instrument is C, a little below the reach of a common voice, and the highest G, including three complete octaves; and they are distinguished by painting the apparent parts of the glasses within side, every semitone white, and the other notes of the octave with the seven prismatic colours; so that glasses of the same colour (the white excepted) are always octaves to each other. The glasses being tuned, they are to be fixed on a round spindle of hard iron, an inch in diameter at the thickest end, and tapering to a quarter of an inch at the smallest. For this purpose the neck of each glass is fitted with a cork, projecting a little without the neck; these corks are perforated with holes of different diameters, according to the dimensions of the spindle in that part of it where they are to be fixed. The glasses are all placed one within another, the largest on the biggest end of the spindle, with the neck outwards; the next in size is put into the other, leaving about an inch of its brim above the brim of the first; and the others are put on in the same order. From these exposed parts of each glass the tone is drawn by laying a finger upon one of them as the spindle and glasses turn round. The spindle thus prepared is fixed horizontally in the middle of a box, and made to turn on brass gudgeons at each end. A square shank comes from its thickest end through the box, on which shank a fly-wheel, to equalize the motion, is fixed. This wheel is made of mahogany, eighteen inches in diameter, and pretty thick, to conceal near its circumference about 25lbs. of lead. An ivory pin is fixed to the face of this about four inches from the axis, and over the neck of this pin is put the loop of a string from a treadle, by which the machine is put in motion. The whole is put in a neat case, and stands on a frame with four legs. The case is three feet long; eleven inches wide at the largest end, and five at the smallest; it is made with a lid, which opens at the middle of its height, and turns up by back hinges: the instrument is played upon by sitting before the middle of the set of glasses, turning them with the foot, and wetting them now and then with a sponge and clean water. The fingers should be first a little soaked in water, and quite free from greasiness; a little fine chalk is sometimes useful to make them catch the glass, and bring out the tone more readily. Both hands are used, by which means different parts are played together. "The advantages of this instrument are," says Dr. Franklin, "that its tones are incomparably sweet beyond those of any other; that they may be swelled and softened at pleasure by stronger or weaker pressures of the finger, and continued to any length, and that the instrument being once well tuned, never again wants tuning."

HARNESS. The furniture and equipments of horses, to adapt them for drawing carriages, and for being driven, guided, and controlled. The constituent parts of harness are noticed under their separate heads. See COLLAR, SADDLE, CARRIAGE, &c.

HARP. A stringed instrument, consisting of a triangular frame, the chords of which are distended in a parallel direction from the upper parts, to one of its sides.

HARPOON, or HARPING-IRON. A javelin used to pierce whales, in the Greenland and South Sea fisheries. It has a broad, flat, triangular, barbed head, well sharpened, to penetrate easily, and a shank about two feet long, to

the extremity of which is fastened a long line, which lies carefully coiled in the boat, in such a manner that it may run out easily, and without entangling. As soon as the boat has come within a competent distance of the whale, the harpooner launches his instrument, and the fish, immediately he is wounded, descends with amazing rapidity, carrying the harpoon along with him, and a considerable length of the line, which is purposely let down to give him room to dive. Being soon exhausted with the fatigue and loss of blood, he re-ascends, in order to breathe, where he presently expires, and floats upon the surface of the water; when they approach the carcase by drawing in the whale line. This line is from sixty to seventy fathoms long, and made of the finest and softest hemp, that it may slip easily. To prevent the boat taking fire by the friction of the line against it, it is constantly watered as it passes out. The harpoon is also employed to catch sturgeons, and other large fish. About a century ago, guns were tried for discharging harpoons, on the presumption that they could strike the whales at greater distances than by hand. They were tried for several seasons, but their employment has been ever since abandoned.

HARPSICHORD. A stringed instrument contained in a large case of wood, having a double or treble row of distended strings, of brass and steel wires, supported by bridges. It is played upon similarly to the piano-forte, but instead of hammers covered with leather, the tone is produced by little upright pieces of wood, called jacks, furnished with pieces of crow-quill, which strike the wires. The piano-forte has now almost wholly superseded the harpsichord.

HARROW. An agricultural implement, used for raking and levelling the earth. There are two principal distinctions; namely, the common, and the jointed chain harrow. The common harrow is usually made by framing together a number of stout parallel bars, by means of the like number of similar bars, equidistant, and crossing the others at right angles, thus leaving uniform square spaces between them. To strengthen this frame, a bar is fixed diagonally across them. The spikes or tangs, which are made from four to twelve inches in length, (according to the nature of the soil, or work to be performed,) are fixed to this frame either by nuts and screws, or by rivetting them down upon iron washers, after passing them through the wood. The frame of course lies flatways upon the ground, with the tangs to the ground, and it is drawn across the field by cattle yoked to a chain fastened to one corner of the harrow. The chain or screw harrow is made to divide diagonally into two parts, thus forming, as it were, two triangular harrows, which are hooked and chained together. This contrivance adapts itself better to the ridges and other inequalities of the ground. Sometimes, in lieu of this, two common harrows are chained together, and applied to effect the same object.

HARTSHORN SHAVINGS. These shavings, although originally taken from the horns of stags, or harts, which are a species of bone, are now obtained chiefly by shaving down with a plane the bones of calves. They afford a nutritious and speedily formed jelly.

HARTSHORN, (Spirit of,) is now usually obtained by the distillation of bones, hoofs, horns, and in general the refuse of slaughter-houses. An iron still or retort is generally used with a pipe leading from it into a worm condenser. The retort is filled with bones roughly broken, or other materials, and a strong heat applied. Water, and a tar-like oil, accompanied with a fœtid inflammable gas, result; carbonic acid also comes over, but this is mostly taken up by the ammonia, which is formed at the same time, and received in the state of carbonate of ammonia. When the different substances have been condensed in the worm, they should pass into a receiver, which has no communication with the open atmosphere, (on account of the overpowering nuisance of its odour,) but which should have a pipe inserted into the upper part of it, and connected with the ash-pit of the still. The inflammable gas and the smell are conveyed to the fire, where the former ignites; but care must be taken to avoid any explosion, for when the evolution of the inflammable gas becomes slow, or ceases entirely, the common air passes along the pipe into the close receiver, which is filled with the same inflammable gas; and, under these circumstances, an explosion will take place, which will not only burst the receiver,

but do other injury. This evil, Mr. Gray observes, may be avoided by placing a valve in the pipe opening outwards, to allow the passage of the gas; and another valve into the receiver, opening inwards; by this means the flaming gas will be stopped in its passage to the receiver; as the valve into the receiver opening, will admit the common air to fill up the vacuum. Thus, by means of this apparatus, if it be well constructed, and proper luting be employed, the distillation of hartshorn may be carried on almost without any smell, although the odour of animal oil is so remarkably offensive. The first product consists of water, animal tar, and volatile salt. A great part of the tarry oil may be separated mechanically; the rest, in a great measure, by a second distillation with a gentle heat. The liquid which comes over consists of a solution of sesqui-carbonate of ammonia, with a fetid animal oil, which gives it a peculiar odour. This liquid is still sold in the shops under the name of spirit of hartshorn, as the alkaline liquor obtained from that substance was at one time thought to possess certain medical virtues, not to be found in the alkaline liquor obtained from other animal matters.

HATS. A well-known covering for the head, and distinguished from a cap or bonnet by a brim. They are made by various methods, according to the nature of the substance of which they are composed; but by far the greatest number are formed of the fur of different animals, by a process called felting: this manufacture has of late years become of considerable commercial importance, and numerous improvements have been introduced into it. The materials for making hats are chiefly rabbits' fur, cut off from the skin, together with wool and beaver, to which may also be added mole fur, and kid hair. These are mixed in various proportions, and of different qualities, according to the value of the hats intended to be made; but the beaver is now wholly used for facing the finer hats, and not for the main body or stuff. The first process in the manufacture of hats is termed *bowing*, which has for its object to separate the fibres, and break up any clots, so as to form the whole into a kind of light down: it is performed as follows—the workman is provided with a pole of ash, or white deal, about seven feet long, having a bridge at each end, over which is stretched a catgut about $\frac{1}{12}$ of an inch thick; and a portion of the material being laid upon a hurdle of wire, he holding the bow horizontally in his left hand, nearly in contact with the material, gives the string a pluck with a wooden pin, held in his right hand. The string, in its return, strikes the fur, and causes it to spring up in the air, and fall in a light open form, at a little distance from the mass. By repeated strokes, the whole is subjected to the bow; and having thus fallen together in all directions, it forms a thin mass or substance for the felt. The quantity thus treated at once is called a *batt*, and never exceeds half the quantity required to make one hat.

When the batt is sufficiently bowed, it is ready for *hardening*, which is the term for the commencement of the felting. The prepared material being evenly disposed on the hurdle, is covered with a linen cloth, and pressed backwards and forwards in its various parts by the hands of the workman. The pressure is gentle, and the hands are very slightly moved backwards and forwards, at the same time, through a space of perhaps a quarter of an inch, to favour the hardening entangling of the fibres. In a very short time, the stuff acquires sufficient firmness to bear carefully handling. The cloth is then taken off, and a sheet of paper, with its corners doubled in, so as to give it a triangular outline, is laid upon the batt, which last is folded over the paper as it lies, and its edges, meeting one over the other, form a conical cap. The joining is soon made good, by pressure with the hands on the cloth. Another batt ready hardened is in the next place laid on the hurdle, and the cap here mentioned placed upon it with the joining downwards. This last batt being also folded up, will have its place of junction diametrically opposite that of the inner felt, which it must therefore greatly help to strengthen. The principal part of the intended hat is thus put together, and now requires to be worked with the hands a considerable time upon the hurdle, the cloth being also occasionally sprinkled with clear water. During the whole of this operation, which is called basoning, the felt becomes firmer and firmer, and contracts in its dimensions. The use of the paper is to

prevent the sides from felting together. The basoning is followed by a still more effectual continuation of felting, called *working*, which consists in plunging them into a cauldron containing water slightly acidulated with sulphuric acid, and then working them upon some planks forming the frustrum of a cone, meeting in the cauldron at the middle. The imperfections of the felting now appear; and the workman picks out the knots and other hard substances with a bodkin, and adds more fur upon all such parts as require strengthening. This added fur is patted down with a wet brush, and soon incorporates with the rest. Towards the close of this working, the beaver for the nap is laid on. By these means, the substance of the hat is formed into a felt of close texture, pliable, and capable of extension (although with difficulty), in every direction, but the figure is still conical; the next thing to be done, therefore, is to give it the required shape. For this purpose the workman turns up the edge or brim to the depth of about an inch and a half, and then returns the point back again through the centre or axis of the cap, so far as not to take out this fold, but to produce another inner fold of the same depth. The point being returned again produces a third fold, and thus the workman proceeds until the whole has acquired the appearance of a flat circular piece, consisting of a number of concentric folds or undulations with the point in the centre: this is laid upon the plank, where the workman, keeping the piece wet with the liquor, pulls out the point with his fingers, and presses it down with his hands, at the same time turning it round on its centre in contact with the plank until he has by this means rubbed out a flat portion equal to the intended crown of the hat. In the next place he takes a block, to the crown of which he applies the flat central portion of the felt, and by forcing a string down the sides of the block, causes the next part to assume the figure of the crown, which he continues to wet and work until it has properly disposed itself around the block. The brim now appears like a puckered or flounced appendage round the edge of the crown; but the block being set upright on the plank, the requisite figure is soon given by working, rubbing, and extending this part. Water only is used in this operation of blocking or fashioning; at the conclusion of which it is pressed out by the blunt edge of a copper implement called a *stamper*. Previous to the dying, the nap of the hat is raised or loosened out with a wire-brush or carding instrument. The fibres are too rotten after the dying to bear this operation. The dying materials are logwood, a little oak bark, and a mixture of the sulphate of iron and of copper, known in the marts by the common name of green copperas and blue vitriol. The hats are boiled with the logwood, and afterwards immersed in the same solution. The dyed hats are, in the next place, taken to the stiffening shop. One workman, assisted by a boy, does this part of the business; he has two vessels or boilers, one containing the grounds of strong beer, and the other containing melted glue, a little thinner than what is used by carpenters. The beer grounds are applied in the inside of the crown to prevent the glue from coming through to the face, and also to give the requisite firmness, at a less expense than could be produced by glue alone. The glue stiffening is therefore applied after the beer grounds are dried, and then only upon the lower face of the brim and the inside of the crown. The dry hat, after this operation, is always rigid, and its figure irregular. The last dressing is given by application of moisture and heat, and the use of the brush, and a hot iron, as before mentioned, somewhat in the shape of that used by tailors, but shorter and broader on the face. The hat being softened by exposure to steam, is drawn upon a block, to which it is securely applied by the former method of forcing a string down from the crown to the commencement of the brim. The judgment of the workman is employed in moistening, brushing, and ironing the hat, in order to give and preserve the proper figure. Before the hat is quite finished, the brims are cut by a knife attached to a radius rod so as to describe a circle; the cut is not carried entirely through, so that one of the last operations consists in tearing off the redundant part, which, by that means, leaves an edging of beaver round the external face of the brim. When the hat is thus finished, the crown is tied up in gauze paper, which is neatly ironed down, and it is then ready for the subsequent operations of lining, &c. for sale.

In that ably conducted work, *Nicholson's Journal*, Vol. IV. 4to, are several suggestions for effecting many of the foregoing operations by machinery. Amongst other subjects proposed for inquiry are the following:—whether carding, which is rapidly and mechanically done, be inferior to bowing; whether a succession of batts or carding might be thrown on a fluted cone, which rapidly revolving in contact with three or more cylinders, might perform the hardening and even the working with much more precision and speed than they are now done by hand; and whether blocking or shaping be not a process extremely well calculated for the operation of one or more machines. These ingenious suggestions have recently been in some measure acted upon.

In 1826 Mr. G. Borradaile obtained a patent for an apparatus for the making or setting up of hat bodies, as it is termed, in which several cones or frustrums of cones are made to revolve upon their axes; and the frames in which these

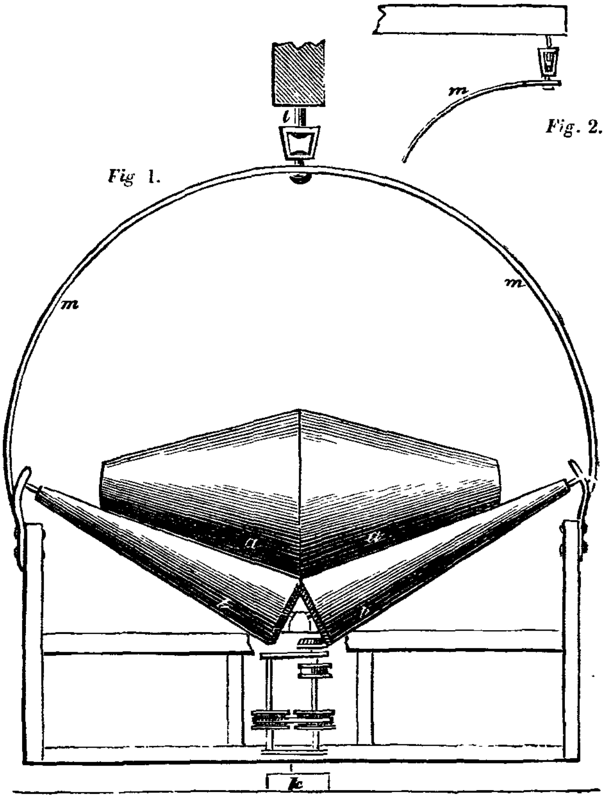


Fig. 2.

Fig 1.

cones act being made to vibrate horizontally on a fixed pivot and swivel, the filaments of wool are caused to traverse each other diagonally, as they are wound upon a double cone, and by that means to produce a matted substance, which is afterwards to be wetted, shrunk, and felted together in the usual manner. The bodies of two hats, each of a conical figure, are thus made over the surface of a double cone, which are separated by cutting them along their middle or base line, and slipping them off at the end. *a a* in the diagram, represents this double conical block, and *b b* two conical rollers, of which there

are two more on the opposite side of the machine, not seen in this view. The axes of these four rollers are placed in such an inclined position as to admit the double cone *a a* to bear equally upon them. The two front cones *b b* have fixed upon their bases two bevelled toothed wheels, which gear into one another as shown; and rotary motion is given to both by the teeth of one of them taking into a bevelled tooth and pinion that revolves upon a vertical spindle, to which motion is communicated by a band and rigger. The large double cone *aa*, therefore, is made to revolve slowly by the friction of its surface against the four conical rollers underneath. The *sliver* of wool being conducted from the doffer of a carding engine, placed behind the machine, to the upper side of the double cone *a a*, and the cones *b b* being made to revolve as before described, causes the sliver of wool to be wound round the periphery of *a a* in an uniform layer. In order to give a diagonal crossing to the filaments, as they are wound upon the double cone, the machine is made to turn partly round horizontally upon the pivot *k* in front, and upon a swivel joint *l* at top, to which the back part of the machine is attached by a bent rod *m m*, the form of which bent rod is explained by the separate *Fig.* 2. The gearing, by which the vibrating motion of the machine is effected, is not brought into view in the figure, as it could not be distinctly exhibited; but it may be easily comprehended that a rotary crank and lever will effect this movement. The plan above described, it will be seen, very closely resembles that suggested by Mr. Nicholson for preparing the bodies of hats; that which we are about to describe as nearly resembles his plan for finishing them.

Mr. Ollerenshaw, of Manchester, about the year 1824, took out a patent for a machine for assisting in the dressing and finishing of beaver or felt hats, by which the ordinary labour in those operations is materially reduced, and the work is completed in much less time. It is constructed on the principle of the lathe, and the apparatus consists of three principal parts or lathes, which are all fixed in one strong frame, and motion is given to them by means of a band passing from any first mover, (as a steam-engine, water-wheel, &c. &c.) The first of these lathes is constructed the same as the common wood-turner's lathe, and is used for the purpose of ironing or dressing the sides of the crown; the block upon which the hat is fixed is made to fit on the chuck of the lathe, and as the hat revolves, the hot iron is applied to the surface by the workman, which quickly smooths the hat, giving it the usual glossy appearance; the velvet cushion, and the various brushes hatters use, are likewise applied, as may be required, while it is thus revolving, till that part of the hat is finished, when it is removed and placed upon the block of the next lathe. This second lathe is constructed with a vertical shaft, so as to produce a horizontal rotary motion to the hat, which is better suited for operating upon the flat part of the crown, and the upper side of the brim, than a vertical motion. The hat having undergone the usual manipulations in the second lathe, is removed to the third, where it is introduced, in an inverted position, into a frame made to receive it, which turns round very slowly in a horizontal direction (the axis being vertical); here the workmen smooth the under side of the brim, by drawing the iron across it from the centre outwards. The hat next undergoes the usual examinations, and pickings-out of the extraneous and coarse hairs; after this, it is again subjected to the former operations of ironing and brushing, which finishes it.

HATCH, and HATCHWAY. Hatchway is the square or oblong opening through a ship's deck; and the cover to it is the hatch, which is sometimes provided with a grating, to admit light and air beneath.

HATCHET. A small axe used with only one hand. See Axe.

HATCHING. The production of chickens, or other animals, alive, from eggs, whether by incubation of the parent, or by artificial heat. Under the article Eggs, we have described the mode of hatching chickens by the heat of ovens. In the next article we shall notice the important art of hatching fish, which is practised with much success in China.

HATCHING OF FISH. The Chinese hatch the spawn of fish, by collecting it on the margin and surface of the water, and then filling the shell of a

newly laid egg with the gelatinous matter that contains the spawn. The hole in the egg is waxed over, and it is put under a sitting hen. At the expiration of a certain number of days, they break the shell in water warmed by the sun. The young fry are presently hatched, and are kept in pure fresh water till they are large enough to be thrown into the pond with the old fish. The sale of spawn for this purpose forms an important article of trade in China.

HATCHMENT. The coat of arms of a dead person, usually placed in the front of the house.

HAUTBOY. A musical instrument provided with keys like a flute, but blown by a reed at one end, and spreading out conically towards the other end.

HAY. Grass dried in the sunshine. The risk of this operation being successfully completed, owing to unfavourable changes in the weather, is well known; and the loss to the farmer in consequence of long continued rains and floods, after the grass is cut, is sometimes very severe. It has occurred to us that a remedy for so serious an evil might be found, in providing some simple temporary erections in the hay field, the cost of which would be far less than the value of the crop saved. Four posts, or hop poles, might be fixed in the ground, so as to form a quadrangle, with one in the middle, of greater height, as a central support, and to form the apex of a conical top or roof. At about a foot from the ground, some very coarse netting might be stretched horizontally from pole to pole, and thereto tied; a quantity of the green hay might be thrown lightly upon this. Then, above this layer, a second floor of net work might be laid, with a sufficient space underneath for the free passage of the air, and upon it a second stratum of the wet hay may be thrown; proceeding in this manner, tier above tier, as high as may be convenient; which, by the assistance of a waggon as a stage, might easily be raised to twelve feet, and be covered either by a tarpaulin, or a conical top of hay. In erections of this kind, the hay would thoroughly dry, and the materials of which they are formed would last many years, might easily be stowed away, and be useful for other purposes. The coarse netting in which woollen rags are packed, made of the tarred strands of old cables, would be very cheap, strong, and durable. The Tyrolese have a method of preserving their hay crops which seems to deserve imitation in this country, as it may be perhaps more generally and easily practised. It is thus described by Mr. Brockedon, in a letter to the Society of Arts, &c. "I have observed, in the course of my journeys in the Alpine districts, that the hay is preserved in the meadows and on slopes, in situations where the cocks are exposed to the action of torrents, by being cocked upon stakes having two or three transverse pieces of wood fixed in them. The stake is light, about five or six inches in circumference, and about four or five feet long. These are kept by the farmers in large quantities, and stowed away compactly during winter, under the overhanging roofs of their dwellings. When used, they are driven upright into the ground at convenient distances, and the grass when cut is thrown upon them: it is supported upon the cross pieces or arms of the hay-stake, on which a large cock may be formed; the lower part is free from the ground, while the outside, raked smooth, carries off the rain; in this manner it is often left for weeks, if necessary; the air freely entering and circulating, dries the hay, and frequently it is never spread, except during part of the favourable day in which it is housed.

HEARTH. The pavement or surface on or over which fuel is burned in apartments. But the term hearth, in naval affairs, implies, the grate and apparatus employed on board ship for preparing the food or messes for the ship's company. It is fixed upon deck, in a small covered building, fitted up with a variety of conveniences for the cook and his operations. The modern apparatus usually comprises a steam boiler, coppers, ovens, hot closets, in addition to a large open fire.

HEAT. See Caloric, also Chemistry.

HELIOMETER, or ASTROMETER, is an instrument invented by Bougeur, for measuring with exactness the diameter of the sun, moon, and planets. This instrument is a telescope, having two object-glasses of equal focal distance, placed side by side, so that the same glass serves for both. The tube of this

instrument is of a conical form, larger at the upper end (which receives the two object-glasses) than at the lower, (which is furnished with an eye-glass and micrometer.) Hence, two distinct images are formed in the focus of the eye-glass, the distance of which depending upon that of the two object-glasses from one another, may be measured with the greatest accuracy.

HELIOSCOPE. A telescope fitted for viewing the sun, without dazzling the eyes, by being provided with object and eye-glasses, that are coloured red or green. Huygens used only a plain glass blacked over the flame of a candle, which he placed between the eye and the eye-glass.

HELIOTROPE, is a sub-species of rhomboidal quartz. It is regarded as a precious stone; the colour green, of various shades, and streaked with red veins. The blood and scarlet-red, and the yellow dots and spots are owing to disseminated jasper.

HELM. In naval architecture, the apparatus for steering or guiding the motion of a ship. The helm is usually composed of three parts—the rudder, the tiller, and the wheel, except in small vessels, where the wheel is unnecessary. The rudder is a long and flat piece of timber, or assemblage of timbers, suspended along the hind part of a ship's stern-post, and turning upon hinges. The tiller is a long beam or lever fitted into the head of the rudder within the vessel, by means of which the rudder is turned to the right or left, as occasion requires. In order that the steersman may remain stationary, so as to see the compass placed in the binnacle, ropes, called tiller ropes, are attached to the end of the tiller, and, passing through leading blocks in the vessel's side, are pulled by the steersman; where an increased power is required, small tackles

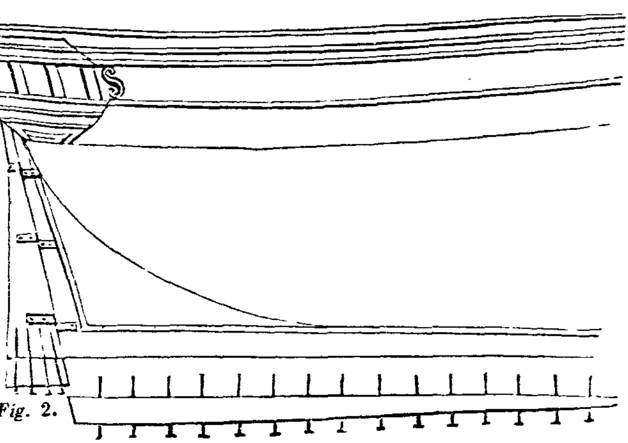


Fig. 1.

Fig. 2.

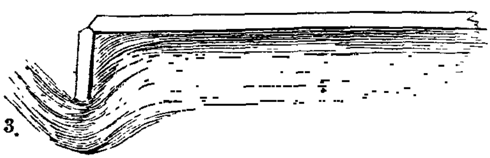
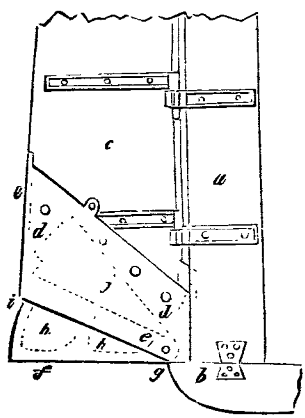


Fig. 3.

are employed: but in large vessels, the tiller ropes are wound upon a barrel or cylinder, which is turned by means of a wheel set upon the same axis, and furnished with six or eight projecting spokes. The effect of the rudder in changing the direction of a ship's head, according as it is turned to either side, arises from the current produced by the vessel's passage through the water striking

more forcibly upon the side which is turned against the current, than upon the opposite side which is turned from it; and, as the rudder placed at the extreme end of a ship may be considered as appended to a lever, the fulcrum of which is somewhere about the centre of the vessel, the pressure thus exerted against it naturally causes the ship to turn upon the centre of gyration, the effect being proportioned to the velocity of the current, and to the angle at which the rudder stands opposed to it. Ships which have what is called a full buttock, that is, carry their breadth very far aft, are found not to answer the helm readily, owing to the water not coming easily to the rudder. To remedy this defect, a false stern-post is sometimes bolted on, and the breadth of the rudder increased. Mr. E. Carey, surveyor of shipping at Bristol, proposes, as a more effectual remedy for vessels having the above defect, to bolt on to the keel a piece one foot six inches abaft, running its breadth two-thirds forwards, then tapered off to nothing as far as the gripe, and to bolt another piece of equal breadth on to the bottom of the rudder (as shown in the drawings, *Fig.* 1 and 2, on the preceding page,) which will make the ship hold a better wind, and answer her helm quickly, and steer perfectly easy. By reference to *Fig.* 3, it will be seen that the effect of the water upon the additional piece will be fully equal to that upon the whole of the rudder before it was put on; for the water rushing along the flat bottom of the vessel, and along the side of the keel, without obstruction, strikes upon the new piece with great force, and at an advantageous angle, and necessarily makes the vessel answer her helm quickly. Ships of war, and other large vessels, if they happen to strike the ground when riding heavily at anchor, or by tailing on a sand bank, are very liable to injure the rudder by tearing it away from its fastenings. To prevent this, Mr. Hillman, of Deptford, proposes that the lower part of the rudder should be made capable of sliding up into a cavity prepared to receive it, and of descending by its gravity into its original position, as soon as the vessel gets clear again. The changes in the construction of the rudder which Mr. Hillman's plan would occasion, are represented in the subjoined figure, which is a broadside view of it. *a* the stern post; *b* part of the keel; *c* the rudder, the bottom of which is cut away to the dotted lines *d d*; *f f* is a metal segment, turning upon the pin *g*, and sliding within the case *e e;* this segment is made hollow from the top on two compartments, as shown by the dotted lines *h h;* it falls by its own weight into the position shown in the figure, and is prevented from coming further by a projection from its top, lodging on a step at *i*, within the case *e e*. The cavity *j j*, from the bottom of the case *e e* to the dotted lines *d d*, is made large enough to receive the whole of the segment *f f*. If, therefore, the vessel should touch the ground, so as to endanger the rudder, this segment would slide into the recess, and thereby avoid the blow, and would fall out again to restore the length of the rudder when clear of the ground. The Society of Arts presented to Mr. Hillman their large silver medal for this invention.



HELIX, in Geometry. is a term generally used synonymously with spiral; but some authors make a distinction between the helix and the spiral. Daviler says, that a staircase is a helix or helical when the steps wind round a cylindrical newel; but that a spiral winds round a cone, and is continually approaching nearer and nearer to its axis.

HELLEBORE. The root of a plant formerly used in medicine, but now nearly discarded from practice, on account of the violence of its operation.

HELMET. A defensive armour for the head, composed usually of the skins of animals and of metals.

HEMATIN. The colouring principle of logwood, which is obtained by digesting alcohol for a day on the aqueous extract of logwood; then filtering the solution, evaporating partially, and leaving the liquid to rest, hematin will be deposited in small crystals, which, after washing with alcohol, are brilliant, and of a whitish red colour, having a bitter, acrid and slightly astringent taste. Hematin forms an orange-red solution with boiling water, becoming yellow as it cools, but recovering with increase of heat its former hue. Excess of alkali converts it first to a purple, then to violet, and lastly to brown. Metallic oxides combine with hematin, forming blue-coloured compounds. Gelatin throws down reddish floculi; peroxide of tin and acid redden it.

HEMISPHERE. One-half of a globe or sphere, formed by a plane passing through its centre.

HENBANE. A poisonous narcotic plant, common in our ditches and road-side. It is sometimes used in medicine. See HYOSCIAMA.

HENNA. A plant growing in Africa and many parts of the East; the colouring matter being much in request for dyeing the finger nails of the inhabitants of the East, and the mains, tails, and hoofs of their horses. The colouring matter of the plant is very abundant, and might be advantageously used for dyeing woollens yellow and brown, of various shades, by combining it with alum and sulphate of iron. The leaves are dried, powdered, and made into a paste for the above-mentioned purposes. The powdered leaves form a large article of export to Persia and the Turkish possessions.

HEPATIC AIR. Sulphuretted hydrogen gas.

HERMETICAL SEALING, is used to denote the perfect closing of vessels so as to prevent the ingress or egress of the most subtle fluids or bodies. In stopping glass vessels, for chemical operations, it is usual to heat the neck until it is quite soft, and then twisting it by a pair of pincers; sometimes a plug well luted serves the purpose effectually.

HIDES. The skins of beasts; the word being, however, distinctively applied to the skins of oxen, cows, horses, and other large thick-skinned animals. Raw or green hides are those which have not undergone any preparation. Seasoned hides are those which have been salted with alum and saltpetre, to preserve them until they undergo the process of tanning and currying. See LEATHER.

HIGH-WATER. That state of the tides when they have flowed to the greatest height, in which state they remain nearly stationary for about fifteen or twenty minutes, when the water begins to ebb. The time of high-water is always nearly the same in the same place at the full of the moon; and at all other times the time of high-water depends upon the age of the moon; the rule for finding which, the age of the moon being given, is as follows: viz. Add four-fifths of the moon's age, as so many hours, to the time of high-water at the full of the moon, and the sum is the time of high water, answering to that day, *nearly*.

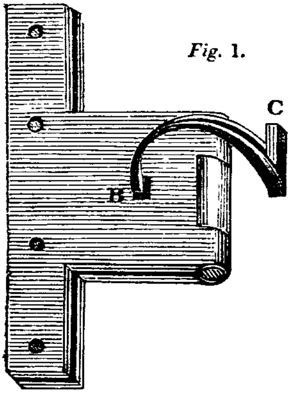
HINGES. The joints on which doors, lids, gates, shutters, and an infinite number of articles are made to swing, fold, open, or shut up. Independently of a great variety of kinds and sizes kept ready made by ironmongers, there is a constant demand for others of novel forms or properties to adapt them to particular objects. The chief varieties are the following:—*cross-garnets*, made in the form of the letter T, for gates and out-house doors, from 6 inches to 36 inches long; and a nearly similar kind made with long straps and hooks to fix in the stiles, to enable the gates or doors to be lifted off their hinges at pleasure. Those used in common for the doors of apartments are termed *butts*, of which there are many varieties. Those used for shutters are called *back-flaps*: similar hinges are used for the joints of bedsteads, and very nearly the same kind for Pembroke and other tables; another sort, called H and H-L hinges, from their resemblance to those letters, are extensively employed for common purposes. There are also many other sorts, distinguished by appellations that designate their uses, and are too numerous to mention. All the various sorts are, or may be made in the different metals, and most of them are to be found

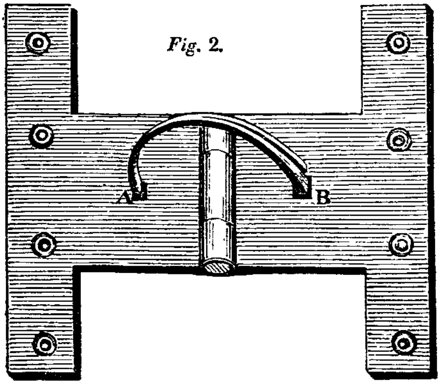
ready manufactured in wrought-iron, cast-iron, and brass, and differently finished. The chief manufactories are at Birmingham, Wolverhampton, Tipton, and several parts of Staffordshire. The best of the wrought-iron kind are made in Lancashire, and the heavier sort at Newcastle. We have several excellent hinge manufacturers in London; amongst whom should be particularly noticed Messrs. Collinge and Son, and Mr. Redmund, on account of their admirable improvements, which have been the subject of patent rights. Instead of the ordinary plan, of a cylindrical joint working round a fixed central pin, Messrs. Collinge form the end, as it were, of the pin, into a sphere, over which a hollow spherical cap fixed to the other limb of the hinge is made to fit accurately; this is provided with a cavity for the reception of oil, having a small perforation to conduct it between the two spherical surfaces, which work with great truth and freedom. The principle of the invention is unquestionably good, and by paying great attention to the manufacture of the article, the inventors have succeeded in obtaining for them a high reputation; they are, in consequence, extensively adopted, especially in turnpike-gates, where their neatness, efficiency, and durability, have established them almost as an indispensable appendage.

Mr. Redmund, of the City Road, has likewise, with great skill and assiduity, bent his attention to the improvement of hinges, in giving them new features and properties, and in finishing them in a style of unusual excellence. We have been informed by an architect of great eminence, that Mr. Redmund possesses a rare degree of ingenuity in adapting hinges to apparently impracticable situations, in giving them an ornamental or a symmetrical appearance where they would in general be deemed a disfigurement, and in rendering them invisible when the style of architecture does not admit of any variations or additions; and that it was on this account that he was employed in rehanging the doors in Windsor Castle, in the recent splendid improvements made in that palace by the late king. This excellent mechanic was educated a carpenter, and being now an engineer and iron founder of some repute, he unites, as it were, within himself, all the resources of his art. Our assigned limits will not permit us to give a detailed description of the variously formed hinges made by this manufacturer, but we will just notice one of them, which is upon the door of the room where we are writing. Those hinges termed rising-butts, whose rubbing surfaces move in a spiral, or rather a helical line upwards on opening the door, causes the latter to descend below the level of the carpet, are probably familiar to enabling it to pass above the carpet on the floor, and which, on shutting the door, most persons; in that case it will not have escaped their notice that doors so hung possess this inconvenience, that they will not stand open of themselves, but are disposed to shut-to, nearly. To obviate these disadvantages, Mr. Redmund cuts from the helical curves two small horizontal planes, so that they come opposite to each other when the door is opened so far as to be at right angles to the stile, that is, having made a quadrant of its circle, at which place the door is consequently at rest, and to shut it when in this position requires a slight pull, which causes the horizontal plane to slide off its support, and the door then returns by its descent on the helix. Persons seldom open a door more than 50 or 60° on entering or leaving a room; consequently, doors hung with these hinges, always shut when left to their own action, and stand open only when they are turned to the full quadrant. In some cases Mr. Redmund assists the door to shut-to closely when opened only a very little way, by the introduction of a very small spring. A variety of these patent hinges may be seen at the manufacturer's warehouse in Frith-street, Soho, London.

Having noticed, a few years ago, the inconvenience (attended with personal danger in some situations) of outside shutters to windows, we contrived a simple addition to the common outside shutter hinges, which completely obviated it. Outside shutters when open, are generally fastened back to the wall by means of those common appendages driven into the wall called turnbackles, which often become loose, broken, or lost; the consequences of which, in windy weather, are, not unfrequently broken windows and broken shutters, besides other inconveniences, which need not be specified. *Fig.* 1 represents

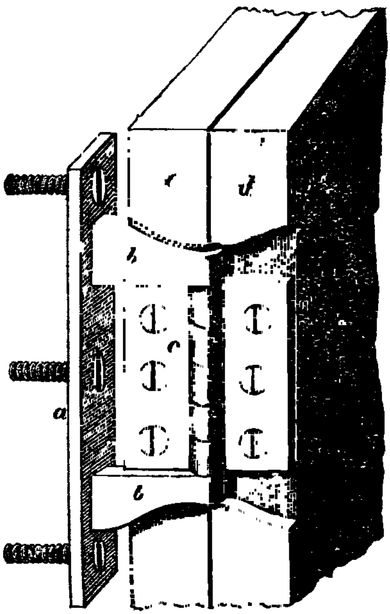
the ordinary hinge shut: and *Fig.* 2 shows it open. A square hole is cut out at A, and into it is strongly rivetted a semicircular piece of iron A B, a portion of it being split in the manner shown, to form it into a spring, and the extremity





being turned upwards to form a stop, as shown at C. Upon opening the hinge the flap B passes over the arc, pressing on the spring, and when arrived at the stop C, it has passed the spring, and is completely open with the shutter *fastened* flat against the wall. When it is required to close the shutter, the spring (which is close to the window) is to be pressed down to allow the flap B to come back over it; and when shut it presents the appearance shown in *Fig.* 1. These hinges are manufactured at only sixpence per pair more than the common sort (the arc being fixed to only the lower one of a pair), and as the troublesome turnbuckle is thereby superseded, the improvement cannot be considered as enhancing the expense.

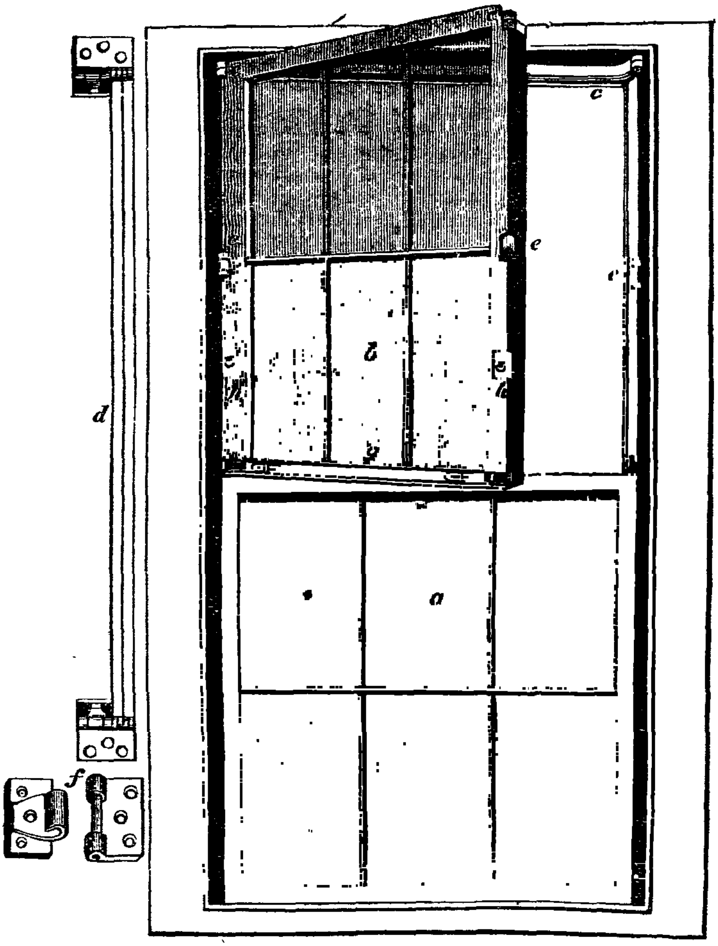
By the ordinary method of hanging doors to libraries, the hanging-stiles are fixed to the vertical partitions of the shelves, and being necessarily of a greater width than the latter, the books behind them cannot be got out without displacing those adjoining. To remedy this inconvenience, the following exceedingly simple and effectual contrivance has been lately adopted by Mr. Nettlefold, of Holborn. *a* is a brass plate, which is screwed to an upright partition; *b b* are two projecting parts (cast in one piece with *a*) with the extremities rounded off, and perforated to receive the centre pin, which passes alike through them and the joint of the common *butt-hinge c*. To the flaps of the latter are screwed the doors *d* and *e*, portions of which are only brought into view to save room. It will be observed that the door *e* lays back quite level with the (supposed) shelves, and that the door



d folds close against *e*, so as to lie parallel with it, and quite out of the way. This being the case, as represented in the figure, it is equally obvious that when the door *d* is turned back the contrary way, both doors are thereby shut, and lie quite flush and close; and that the door *e* may then in like manner be folded over *d*. The greatest facilities are thus afforded by a *single* hinge instead of *two* hinges, and without the necessity of any additional hanging stile.

Whitechurch's patent hinge, for enabling doors and windows to be opened either on the right or left hand, from its utility and convenience, besides the ingenuity of the contrivance, deserves particular notice. It is equally applicable to window-sashes, book-cases, and the show-cases of shops; but its advantages will be most conspicuous in packets, steam-boats, and those situations in particular where the utmost convenience in a small compass is the object of study. The engraving on the following page represents the application of the invention to the sash windows of houses; and its chief utility in these consists in the facility afforded in cleaning that part of the window in perfect safety which has heretofore been done at considerable personal peril, and in very many instances has caused fatal accidents. Its application to a door is, in principle, the same as to a sash thus made (which opens on either side like a door); and our description of the hinges and fastenings therefore will, in a great measure, apply to both. *a* represents the lower sash, suspended over pulleys by lines and weights in the usual manner. To open the upper sash *b*, a false or movable sill is taken out from the lower part of the sash-frame, which enables the sash *a* to descend lower in the frame, and the upper sash, which was previously behind it (or deeper in the frame) to pass over it, and to swing on its hinges on either side. At *c c c* is a pair of long double acting hinges, shown connected on one side of the window, and separated on the side where the window is open. A pair of these hinges is shown shut up and complete by the distinct figure *d*. At *e e e* is shown a pair of small auxiliary hinges; and a single hinge of the kind at the separate figure *f* shows their precise construction. A brass bolt *g* is fixed on the lower stile of the sash, and extending its whole length; about two inches from the end of the bolt it is jointed, so that when either end is shot into its mortice, it acts as a kind of support, and as a centre for the lower part of the sash to turn upon. *h h* exhibit two small latches for securing or opening the sash on either side. Now when the window is opened on that side which is at present closed, exactly the same appearances will be presented, only on the opposite side. It is therefore clear that the hinges must alternately separate and connect themselves at the joints. The manner in which this is done will be partly understood by reference to the separate figure *f*, where each flap of the small secondary hinges is shown apart, as also their connecting themselves by the jointed parts of one flap hooking into another. The long hinges used in the upper part are, however, of a more complex nature, and it is very difficult to give an intelligible description of them without the aid of several more figures, giving different views of their parts, which would occupy too much of our space. Any person, however, who may be desirous of investigating their principles and mode of action, will, we doubt not, have every facility afforded them at the office of the patentees. In applying the invention to a room-door, the arrangement is somewhat different; the long hinges are placed at top as in the case of the window-sash, and the small auxiliary hinges are fixed near to the bottom. On the middle stile of the door, the bolt, or locking bar, is situated, which is either let in flush with the door, or lies in a mortice passing from one side to the other, and is consequently entirely out of sight. A mortice lock is placed on each side of the door, for opening and shutting it by means of the knobs, and the bolt springs to and fastens the door itself, when shut in the ordinary way; and when it is required to open the door the contrary way to that which it was the last time, an extra half-turn of the knob throws back the bolt, and locks the opposite side; it is thus opened on either side instantaneously, and is hung on the opposite side at the same moment with never-failing security. The door is, in fact, more securely hung, is better supported, and, consequently, turns on its hinges with greater ease and

smoothness. It cannot be taken off its hinges without the aid of a turn-screw, as in other doors.



HIP ROOF. A roof, the ends of which rise immediately from the wall-plate, with the same inclination to the horizon as its other two sides. The *backing of a hip* is the angle made on its upper edge to range with the two sides or planes of the roofs between which it is placed.

HIVE. A receptacle for bees. See Bee-hive and Honey.

HOD. A portable receptacle in which bricks, mortar, &c. are carried by labourers in house-building.

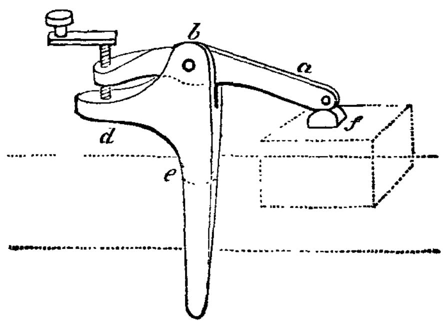
HOE. An instrument employed in agriculture in breaking-up earth, and drawing it around plants. It consists of a broad blade of iron or steel, with an eye or socket in the middle of its upper side, through which a handle is put. Garden and field-hoes are generally about three inches deep in the blade, and from one inch to ten inches in length; but there is a much larger kind, made of

various forms, equal in dimensions to ordinary spades and shovels, which are manufactured in this country for colonial use, chiefly for the cultivation of the sugar-cane. The demand for these articles, not only for the British settlements but for most other parts of the world, is so extensive as to constitute a considerable manufacture at Bristol, Birmingham, Sheffield, Newcastle, and other places.

HOGSHEAD. A measure of capacity, or a cask of a certain determinate size, for holding liquids. The wine hogshead is three-fourths of a puncheon, one-half of a pipe, and one-fourth of a tun; it contains a tierce and a half, or 63 gallons, or 252 quarts, or 504 pints, or 14,553 cubic inches. The beer and ale hogshead is half a butt, and contains a barrel and a half, or 3 kilderkins, or 6 firkins, or 54 gallons, or 216 quarts, or 432 pints, or 15,288 cubic inches; consequently, the wine hogshead is to the beer or ale hogshead as 539 to 564. There are also hogsheads for sugar, flour, peas, and other dry goods; but of these the capacities are not fixed.

HOLD. The whole interior cavity of a ship comprehended between the floor and the lower deck throughout her entire length.

HOLDFAST, Carpenters', is the name of a very useful tool, employed not only by carpenters, but by other mechanics, for *holding fast* their work upon the bench whilst being operated upon. It usually consists of a round bar of iron, thickening a little upwards, and bent at the upper end, almost into a right angle, and flattened. An oblique hole is bored in the bench; and if a piece of wood, or any other article, is wanted to be secured, it is placed under the holdfast, and a few strokes of the hammer are sufficient to make it bite firmly. In order to loosen it, nothing more is necessary than a blow of the hammer applied at the lower end of the bar.



Mr. W. Dungey, of Compton-street, Soho, has succeeded in improving this instrument, for which he received a reward from the Society for the Encouragement of the Arts, &c. It is represented in the subjoined cut. The jaw *a*, instead of being one piece with the rest of the bar, is movable on the screwed axis *b*, and is prolonged backwards. In this latter part is a hole for the reception of a cranked screw, which bears on a projection *d* of the main bar; *e* is the hole in the bench, and *f* is a flat square piece fixed by a loose joint to the jaw *a*, and therefore capable of bearing by its whole surface on any piece of work placed under it. By turning the screw *c* in one direction the work is held fast; and by turning in the other direction it is released. It is considered as likely to be of service to coachmakers, carvers, and chair and cabinet manufacturers, as the pressure of it is under perfect regulation, and it is not liable to bruise the work which it is employed to hold.

HOLDFASTS. A general term applied to a variety of flat-sided iron spikes, that are driven into the joints of brick-work, against which it is desired to fasten any kind of wood-work; for this purpose, the other ends of the holdfasts are spread out so as to lie flat against the wood, whereto these are nailed or screwed through holes made in the iron. The term holdfast is likewise applied to those iron ties in the form of the letter *S*, which are commonly fixed to walls to keep the mass from separating.

HOLLAND. A closely woven kind of linen cloth, of a peculiar fabric, so called from its having been originally imported from Holland.

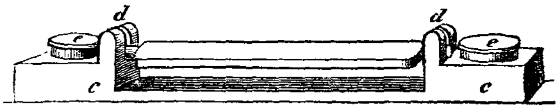
HOLLOW WALL. A wall built in two thicknesses, leaving a cavity

between, which may be either for saving materials, or for preserving an uniform temperature in apartments.

HOLOMETER. A mathematical instrument that serves universally for taking all measures, both on the earth and in the heavens.

HOMBERG'S PHOSPHORUS. Ignited muriate of lime.

HONE. A fine grained kind of stone, used for sharpening razors, penknives, and other cutting instruments. The exquisite edge given by cutlers to razors, lancets, &c. can rarely be produced by those persons who are not in the habit of using them. This arises partly from ignorance of the properties in which consists the difference between a good and a bad hone, and partly from a want of that skill and slight of hand in the use of a hone, which long and constant practice only can give in perfection. Mr. Fayrer, of Pentonville, has, however, constructed a novel kind of hone, by the use of which the unskilled and inexperienced operator may, without difficulty, produce a good edge. This



hone consists of a plate of brass *a* about an inch wide, and of any convenient length, ground to a perfectly smooth surface on both sides, one of which is marked R and the other S; part of each end is cut or filed away, leaving only two pins or pivots, on which the hone turns or swings. In the frame *c c* are two uprights *d d*, with notches to receive the pivots; *e e* are two boxes, one to hold a coarser and the other a finer powder, made of oil-stone ground down and washed over: for the latter, finely pulverized water-of-Ayr stone may be substituted. To use this hone, first place the side marked R uppermost, and put on it a few drops of oil and a little of the coarser powder, then draw along it in the usual manner the edge of the instrument to be sharpened. As the hone swings on two pivots, the surface necessarily applies itself quite evenly along the edge of the blade, in whatever direction the pressure of the hand is made that holds the tool; and the particles of the powder, as the operation proceeds, are continually becoming smaller and smaller, and therefore giving a finer and finer edge. To finish the setting, turn uppermost the surface of the hone marked S, apply to it oil and the finer powder, and proceed as before.

HONEY. A sweet and scarcely fluid substance, which is collected by bees from the nectaria of flowers, and deposited in the cells of the combs for the support of the bees and their offspring. Naturalists are not agreed whether honey undergoes a particular elaboration in the bodies of bees, thence deriving its flavour and consistence, or whether it is merely collected and deposited by them in its pristine state. M. Cavezzali has proved that honey is composed of sugar, mucilage, and an acid. The sugar may be separated by melting the honey, adding carbonate of lime, in powder, as long as any effervescence appears, and scumming the solution while hot. The liquid, thus treated, gradually deposits crystals of sugar. There are three distinctions of honey, according to its purity and the manner it has been obtained from the honey-combs. The first and finest kind is virgin honey, or the first produce of a swarm, obtained from the combs without pressing, these being only set to drain, in order to its running out. The second kind is that known by the name of white honey, being thicker than the former, and often, indeed, almost solid; it is procured by pressing the combs, but without the assistance of heat. The third and worst kind is the common yellow honey, obtained from the combs first heated over the fire, and then pressed. Honey was a domestic manufacture of great importance before the introduction of cane sugar; and in those countries where cane sugar is still scarce, the preparation of honey is very

extensively conducted. It is not uncommon for a peasant of the Ukraine to have 4 or 500 hives; and for a parish priest in Spain to have as many as 5000 hives. In the *Hanoverisches Magazin*, it is stated that the Jews in Moldavia have a method of making honey into a hard and white sugar, which is employed by the distillers of Dantzic, to make their liqueurs. The process consists in exposing the honey to the frost during three weeks, sheltered from the sun and snow in a vase of some material which is a bad conductor of heat. The honey does not freeze, but becomes transparent, and hard as sugar.

HONEY-COMB. The cellular fabric made by bees in wax, in which they deposit their honey. Hence, in the casting of iron or other metals, when the work is not solid, but cellular or spongy, it is denominated *honey-comb*.

HOOD. A cowl or covering, placed on the top of any thing.

HOOD and MOUTH PIECE, invented by Roberts, the miner, for descending mines, or going into houses on fire, is described under FIRE ESCAPES.

HOOFS. The horny substance that covers the feet of various animals; it chiefly consists of coagulated albumen. See HORN.

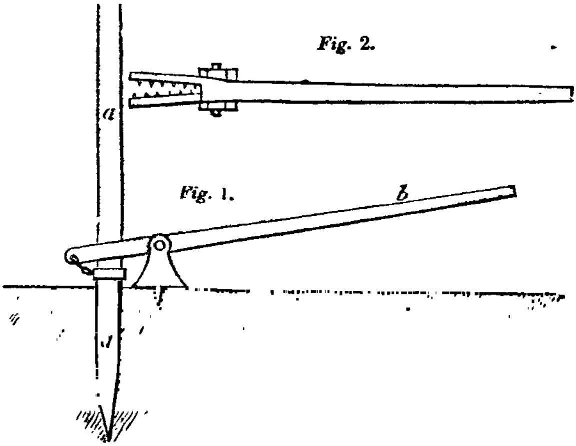
HOOP. A pliant piece of wood or metal made into rings, or circular bandages for casks, &c.

HOPPER. A trough or funnel employed to supply corn to a mill, fuel to close furnaces, and to a great variety of other purposes.

HOPS. The dried flower buds of a British climbing plant, which grows wild in many parts of England; but for the purposes of commerce and brewing, they are usually cultivated in extensive plantations, where they require the growth of some years before they attain perfection. To cultivate it with success requires extreme care, considerable experience, and a large capital; yet perhaps of no plant is the harvest so precarious, from an unfavourable season, and the depredations of insects. There are several varieties of it, as the *red bind*, the *green bind*, and the *white bind*. It is propagated by nursery plants, or by cuttings. These are planted in little hillocks, formed by digging a hole 12 inches deep and 18 inches in diameter, and filling it up with fine mould, mixed with manure, and the original soil. In the centre of the hill is set a single plant, and round it half a dozen others. The hills are about 9 feet asunder. Cuttings are set in February and March, but sets, or nursery plants, in autumn. In April, if the season be favourable, the binds require tying to poles, which are stuck in the earth. About Midsummer they are pruned, and the produce given to cattle. In September they are usually ready for pulling. Chestnut is reckoned to make the best poles, and ash the next—the poles are from 18 to 24 feet in length; three poles are sufficient for a single hill, or two poles where the plants are vigorous. The large poles are not required till the first winter after the plantation has been formed, and it is advisable not to take any produce the first year. The picking is performed by men, women, and children. Proper baskets and bins or cribs being in readiness, the plants are cut off close to the ground, and the poles drawn up; these are placed upon the bins, with the plants upon them, and three or four persons on each side pick off the hops. After this, they are dried in a kiln; and when dry they are carried into, and kept for five or six days in a room called the stowage room, until they are in a state to be put into bags. This is done through a round hole or trap, cut in the floor of the stowage room, exactly equal to the dimensions of the mouth of the bag, and immediately under which, to a frame of wood, this mouth is fastened. In each of the lower corners of the bag a small handful of hops is tied; and a person called the packer places himself in it, and by a heavy leaden weight, which he constantly moves round in the places where he is not treading, presses and forces the hops down in a very close manner into the bag, so fast as they are thrown to him by another labourer. The work thus proceeds until the bag is quite full, when each of the upper corners has a few hops tied in it in the same manner.

The usual way of extracting hop poles, by pushing them backwards and forwards till they are sufficiently loosened to be raised up out of the ground by hand, subjects the hops to injury, by shaking and bruising them, while the poles

themselves are frequently broken. These inconveniences are avoided, and a considerable time is saved, by the application of an apparatus invented by Mr. John Knowles, of Farnham, who took out a patent for it in 1830. The nature of the contrivance, and the intention of the inventor, are well expressed on the title of the patent, which is for "a certain instrument or machine for drawing up hop poles out of the ground previous to picking the hops, and which, by drawing the poles perpendicularly, will greatly save them, as well as prevent the hops from being bruised, called a hop-pole-drawer, by lever and fulcrum." In the annexed engraving, *Fig.* 1, is shown a portion of a hop pole, and the application of the lever and fulcrum in raising it out of the ground; *a a* is the pole,



b the lever, and *c* is its fulcrum, which has a broad base, with a short spike to prevent its slipping when the pressure is applied to it. *Fig.* 2 shows a plan of the lever with its iron jaws, which are made to approach each other, that some part of the opening may fit all sizes of poles; and they are serrated to prevent their slipping upon the poles.

HORN. An animal substance, composed of coagulated albumen, with a little gelatine, and about a two-hundredth part of the phosphate of lime. But the horns of the buck and hart are of a different nature, being intermediate between bone and horn. The horns of oxen are prepared for lanthorn leaves in the following manner. They are first softened by roasting over a fire made of the stalks of furze, and then slit lengthwise, on one side, and kept expanded flat between a pair of tongs, and afterwards placed in a press between iron plates that are greased. Here the horns remain till they are cooled; they are next soaked in water till soft enough to be pared down to the required thinness, with a large knife worked horizontally on a block. Their transparency is thus acquired; and after being immersed in ley, they are polished with whitening, and the coal of burnt willow. Horn for making into snuff boxes, combs, and other ornamental articles, are stained to imitate TORTOISE SHELL, which see.

HORN. A musical instrument of the wind kind: the earliest, from which the instrument derived its name, were the horns of animals, and these are still used extensively in remote or uncivilized districts. Considered as a modern musical instrument, they are chiefly made of metals, and of various kinds or forms. The French horn is a long tube, narrow at the top, and increasing in diameter to the end, where its mouth is very wide. It is curled up in several rings, for the convenience of carriage and performance. The trumpet and the bugle horn are noticed under their respective heads.

HORN, ARTIFICIAL, or Tanned Gelatine. Considerable manufactories have, it is said, been established in France, for the construction of a variety of articles with this substance. The gelatine is usually obtained from bones, by treating them with a weak solution of muriatic acid; and it is afterwards tanned by the common process, as in making leather. Upon becoming hard and dry, it assumes the appearance of horn or tortoise shell, and is employed for the same purposes as those substances. It is softened by being boiled in water with potash, when it may be formed into any shape, and the figure preserved by drying the articles between moulds. In the soft state, it may also be inlaid with gold, silver, or other metals, and is streaked with various coloured materials, so as to resemble the finest woods and other natural productions.

HORNBLENDE. A species of the clay genus, of which there are three varieties; viz. the common, hornblende slate, and basaltic hornblende.

HORN-ORE. One of the species of silver ore.

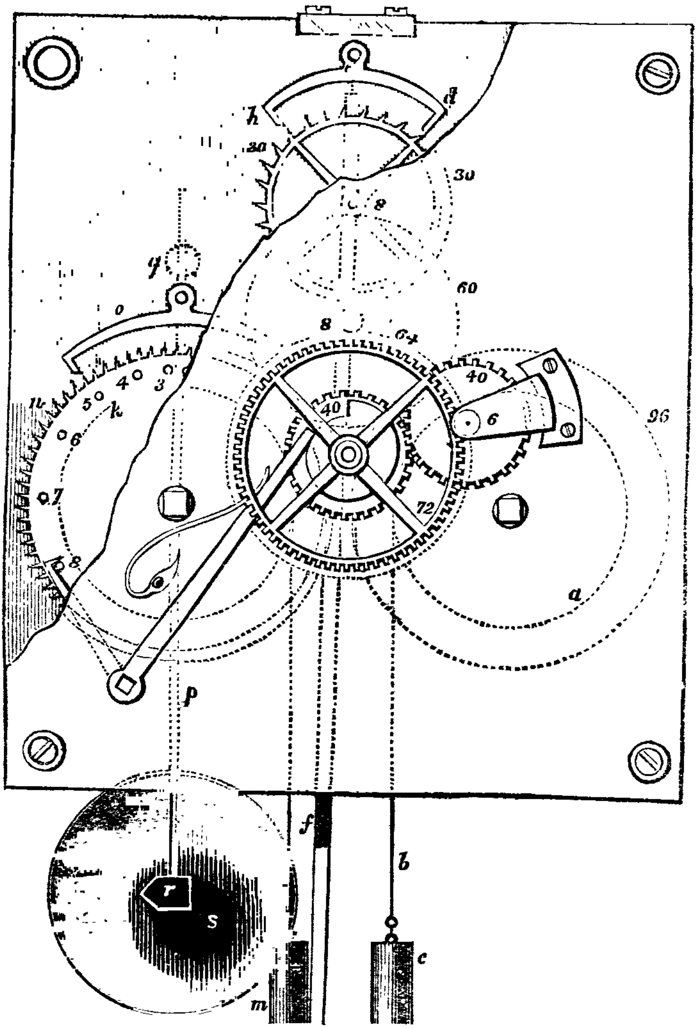
HORNSTONE. A sub-species of rhomboidal quartz, according to Jameson, who divides it into splintery hornstone, conchoidal hornstone, and woodstone.

HOROGRAPHY. The art of Dialling, which see.

HOROLOGY. The art of constructing machines for measuring time; but from the circumstance of clocks and watches having very generally superseded all other contrivances for this purpose, the term is now usually understood as referring to these latter instruments solely. In these machines a pendulum, or a spiral spring, connected to a flat wheel turning freely on its axis, (called a balance wheel,) is made to vibrate; and it being a property of these bodies, that all the vibrations, whether through large or small arcs, (within certain limits,) are made in equal times, all that is necessary to measure time by this means, is to register the vibrations, and to prevent the vibrating body from being brought to rest by the resistance of the atmosphere, or the friction of its parts, about the centre of oscillation; and these objects are effected by means of a train of wheels put in motion by the descent of a weight, or by the action of a coiled spring, the velocity of the wheels being regulated by the vibrations of the vibrating body. The essential difference between clocks and watches consists in the nature of the regulator employed; which in clocks is the pendulum, and in watches the balance wheel. The pendulum requires to be suspended from steady points of support, that its vibrations may be constantly performed in a vertical plane, hence clocks cannot be made portable; but from the pendulum being acted upon by the force of gravity, which is a constant force, its motion is more equal than that of the balance spring, the force of which varies greatly, from changes of temperature, and other causes; clocks are therefore always preferred in observatories; but as the balance will perform lying in any position, watches have the advantage of being portable.

We shall now proceed to describe the construction of an ordinary eight-day clock, which we hope will be rendered sufficiently clear with the help of the accompanying engraving, which exhibits a front view of the works, the dial plate being removed to show the manner in which the hour and minute hand are made to revolve with different velocities upon the same centre. A portion of the front frame plate is likewise represented as broken away to exhibit more clearly the escapement; the striking parts, and the wheels and pinions composing the train, being hidden by the frame plate, are represented simply by dotted circles, and instead of letters of reference, they are indicated by figures, which express the number of teeth contained in them. The striking parts, as usually constructed, are so very complex as to render it extremely difficult to convey a clear idea of their operation without a very lengthened description, and several diagrams; we have therefore preferred introducing in their stead an extremely simple and ingenious arrangement for the purpose, invented by Mr. Prior, of Nessfield, in Yorkshire, and for which he received a reward from the Society of Arts. A clock of this kind contains two independent trains of wheelwork, each with its separate first mover; one is constantly going to indicate the time by the hands on the dial plate; the other is put in motion every

hour, and strikes a bell to tell the hour at a distance; the dotted circle *a* is the barrel of the going part; it has a catgut *b* wound round it, suspending the weight *c* which keeps the clock going; 96 is a wheel (called the first or great wheel,) of that number of teeth, upon the end of the barrel, turning a pinion



of eight leaves, on an arbor which carries the minute hand. 64 is a wheel of 64 teeth, on the same arbor, (called the centre wheel,) turning the wheel 60, by a pinion of eight leaves on its arbor: this last wheel gives motion to the pinion of eight, on the arbor of the swing wheel 30, of 30 teeth; *d h* are the pallets of the escapement, fixed on an arbor *e*, going through the back plate of the clock's frame, and carrying a long lever, which has a small pin projecting from its

lower end, going into an oblong hole, made in the rod *f* of the pendulum. The pendulum consists of an inflexible metallic rod, suspended by a very slender piece of steel spring, from a brass bar, screwed to the frame of the clock, having a weight or bob at its lower end, in the present case 39.125 inches from the point of vertical suspension; when this pendulum is moved from the line in either direction, and suffered to fall back again, it swings nearly as much beyond the vertical on the contrary side, and then returns; this it will continue to do for some time, and each of these vibrations will be performed in one second of time, when the pendulum is of the above length. This is the measurer of the time; and the office of the clock is only to indicate the number of vibrations it has made, and give it a small impulse each time to keep it going, as the resistance of the air, and elasticity of the spring, would otherwise in a few hours cause it to stop. By the action of the weight applied to the cord *b*, (which is called the maintaining power,) the wheels are all turned round; and if the pallets *d h* were removed, the swing wheel 30 would revolve with great velocity in the direction from 30 to *d*, until the weight reached the ground; the teeth of these pallets are so made that one of them always engages the wheel, and prevents its turning more than half a tooth at a time. In the drawing, the pallet *d* has the nearest tooth of the wheel resting on it, and the pendulum is on the side *h* of the perpendicular; when it returns it moves the pallet *d* so as to allow the tooth of the wheel to slip off; but in the mean time the pallet *h* has interposed its point in the way of the tooth next it, and stops the wheel till the next vibration or second; the distance between the two pallets *d h* is so adjusted that only half a tooth of the wheel escapes at each vibration; and as the wheel has 30 teeth, it will revolve once in 60 vibrations of one second each, or one minute; consequently a hand on the arbor of this wheel will indicate seconds on a circle on the dial plate divided into 60; the pinion of eight on its arbor is turned by a wheel of 60, which consequently will turn once in seven turns and a half of the other, or in seven minutes, 30 seconds, or one-eighth of an hour; its pinion of eight is moved by a wheel of 64, or eight times itself, which will turn in one-eighth part of the time, this will be an hour; the arbor of this wheel, therefore, carries the minute hand of the clock. The great wheel of 96 being twelve times the number of the pinion eight, will turn once in 12 hours, and the barrel *a* with it. The catgut goes round 16 times, so that the clock will go eight days. The hour-hand of the clock is turned by the wheel work shown upon the front frameplate; on the end of the arbor of the centre wheel 64 a tube is fitted, so as to go round with it by friction; this carries the minute hand, but if the clock should require correction, the hand may be slipped round without moving the wheels: this tube has a pinion of 40 teeth on its lower end, indicated by a dotted circle; this turns another wheel 40, of 40 teeth, which has a pinion of 6 teeth on its arbor, turning a wheel 72, of 72 teeth; the two wheels 40 will both turn in an hour, and 72 in 12 hours; the arbor of this wheel has the hour-hand, and is a tube going over the minute-hand, so that the two hands are concentric. The barrel *a* is fitted to an arbor coming through the plate of the clock, and is filed square to put on a key to wind up the weight; the great wheel 96 is not fixed fast to the arbor, but has a click on it, which takes the teeth of a ratchet wheel cut upon the barrel; so that the barrel may be turned in the direction to wind up the weight without the wheel; but by the descent of the weight, the wheels will be turned by the click.

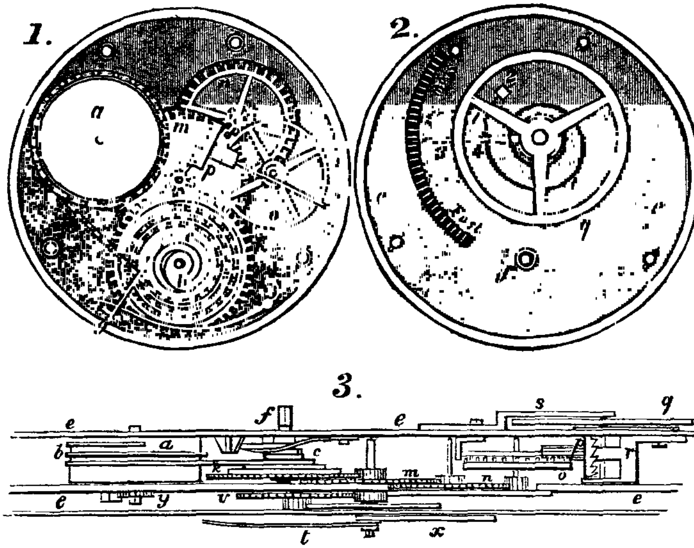
In commencing our description of the striking parts, we should observe, that Mr. Prior not having exhibited their connexion with the going parts of a clock, we have chosen the mode of unlocking the detent which appeared the simplest, and admitted the easiest explanation; but various other and perhaps better modes might be contrived for effecting this: the dotted circle *k* has a weight *m* suspended from it by a catgut passing round it like that which passes round the going barrel *a*; *n* is a scape-wheel of 78 teeth, connected with the barrel by a ratchet and click, and having 12 pins projecting from its face, a portion of which are seen, marked 2, 3, 4, 5, 6, 7, 8; these pins are ranged in a circle at unequal distances, corresponding to the number of strokes to be struck at each

successive hour; *o* is the scapement similar to that previously described; on its arbor is fixed a pendulum *p*, of about nine inches in length, and which will therefore vibrate half seconds nearly; but in order to regulate the rate of vibration at pleasure, the rod of the pendulum is prolonged beyond the point of suspension, and carries a small ball *q* moving stiffly upon it, and by raising or lowering this ball the vibrations become retarded or accelerated. To the lower end of the pendulum rod is attached a hammer *r*, which strikes upon a bell *s* at every second vibration; this effect is obtained by placing the bell sufficiently oblique to allow the hammer to swing past it at one vibration, and to impinge upon it at the returning one. The barrel *k* and escape-wheel *n* are retained at rest by the locking detent *t*, which engages each of the pins in succession on the face of the escape-wheel; this detent is fixed on to the arbor of the arm or lever *v*, which is pressed by the spring *w* against a snail or cam *a* fixed upon the hollow arbor which carries the minute-hand. The snail is consequently carried round once in an hour, during which time the lever *v* is gradually elevated, and moves the detent in like manner until the lever arrives at the highest part of the snail, when the pin on the escape-wheel is released from the detent, and the wheel immediately begins to revolve and imparts motion to the pendulum, which, as before said, strikes upon the bell at each second vibration. The rotation of the snail having carried its highest point past the end of the lever, the latter (pressed by the spring *w*) falls past the straight side of the snail to the foot of the same, and brings the detent into its locking position; and when, by the revolution of the escape-wheel, the next pin comes in contact with the detent, the motion of the wheel is arrested. Clocks are sometimes impelled by springs instead of weights, as in the one just described, and are very convenient for placing in chambers on account of their occupying less room than weight-moved clocks. The construction of these spring clocks resembles that of the other, with the exception that for the barrel and weight are substituted a fusee and spring barrel, resembling the same pieces in a pocket-watch, to the description of which we shall now proceed.

The essential difference, as we have before observed, between a clock and a watch, consists in the former being regulated by a pendulum, and the latter by a balance; for as to the maintaining power, it is sometimes the same in both, since although watches are not impelled by weights, clocks (as just mentioned) are sometimes kept in motion by springs like watches. The balance is a small wheel fixed on an arbor or axis called the verge, and moving freely upon pivots at the ends of the arbor. To the axis of the balance the inner end of a very elastic helical spring called the pendulum is attached, and the outer end is made fast to some fixture. In this state the balance will remain at rest when the spring is in that position which it would assume if detached from the balance, and at perfect liberty; but if the balance be turned on its pivots in either direction, so as either to wind up or unwind the spring, the latter will, upon the external force being removed, tend to resume its natural position; but the momentum which is thus imparted to the balance will carry it past the position of rest, which will again alter the spring, and the balance will again be returned past the position of rest, and will thus continue to vibrate until the friction of the pivots and the resistance of the air destroy the original impulse. The vibrations of such a balance, which passes through equal spaces, will be performed in equal times; these vibrations, therefore, form the real measure of time, and the remaining apparatus in a watch is for the purpose of registering the vibrations, and of maintaining the motion of the balance; and this is accomplished in watches by means of a train impelled by a spring and fusee. The spring employed for this purpose consists of a long flat plate of steel, coiled up in a helical form; it is inclosed in a cylindrical box called the spring barrel, to which its external extremity is attached, whilst its internal end is connected to a fixed axis, round which the barrel revolves. As the strength of the spring is greater the more it is coiled up by turning the box, its action would be unequal in impelling the work of the clock; and to remedy this inconvenience, the fusee has been contrived. The fusee consists of a conical barrel, round

which a spiral groove is cut, which receives a chain previously wound round the barrel, by which, as it is turned round, it coils up the spring; the groove receives the chain first near the base of the cone, and as the barrel revolves, gradually brings it nearer the axis; by this means the stronger the spring is coiled up, the shorter is the lever by which it acts upon the work; and as it gradually uncoils and becomes weaker, on the contrary the lever of action becomes longer.

Having thus explained the nature and operation of the regulator, and of the maintaining power, we shall endeavour to describe the construction of an ordinary watch, with the assistance of the annexed engravings. *Fig.* 1 represents



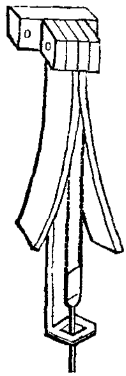
the works, the upper plate being removed; *Fig.* 2 is the upper plate, with the cock removed to show the balance; and *Fig.* 3 a general elevation, supposed to be set out upon a straight line, in order to show the whole at one view. The same letters of reference are used to denote the same parts in all the figures. *a* is the spring barrel; *b* the chain attached by one end to the barrel, and after being wound several times round the barrel, hooked by the other end to the fusee *c*, mounted on pivots turning in holes in the two plates *e e;* one of these pivots *f* projects a considerable distance, and is cut square to receive a key, by turning which the fusee is turned round so as to wind the chain upon it, which causes the spring barrel to revolve also, and coils up the spring into a closer spiral than it was when at liberty; and upon the key being removed, the spring reacts upon the chain, and by that means turns the fusee. To prevent overwinding, a guard is added, which consists of a small lever *g*, which, when the fusee has received a certain number of turns of the chain, presses against a stop *h* on the top of the fusee. *k* is the great wheel attached to the base of the fusee by a ratchet and click, by which means the fusee can be wound up without turning the great wheel; this latter has 48 teeth, and turns a pinion of 12 teeth on an arbor in the centre of the watch, which carries the minute-hand: upon this arbor is fixed the centre wheel *m*, of 54 teeth, working in a pinion fixed upon the arbor of the third wheel *n*, of 48 teeth, which turns the pinion of the contrate wheel *o*, of 48 teeth; the contrate wheel gives motion

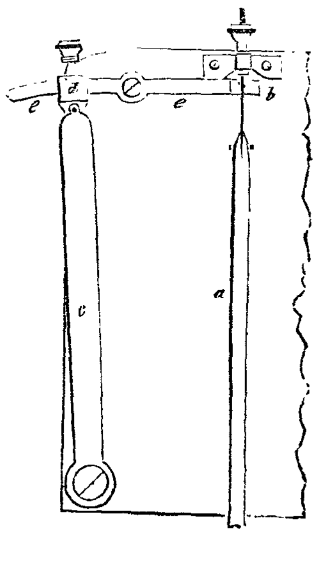
to a pinion of 6 teeth, which is fixed upon the arbor of the crown or balance-wheel *p*, which has 15 large teeth, that stop against two pallets alternately upon the verge or arbor of the balance *q*; these pallets are two small teeth projecting from the verge at nearly right angles to each other, and constitute the escapement, the object of which, as in a clock, is to prevent the train running down rapidly by the action of the main spring, as would be the case if there were no check to it; but at each vibration of the balance, one of the pallets engages a tooth of the crown, thereby retarding the motion of the train, and imparting fresh impetus to the balance; and no sooner has the pallet swung clear of the tooth, but the other pallet engages another tooth on the opposite side of the wheel. One of the pivots of the balance works in a small frame *r* called the potence; the lower pivot of the verge works in it also, and the upper pivot turns in a cock *s* screwed to the plate *e*. The minute-hand *t* is fixed upon the outer end of a tube which fits tight upon the arbor of the central wheel, and which carries upon its inner end a pinion of 12 teeth; this pinion turns a wheel *v* of 48 teeth, on whose arbor is a pinion of 16 teeth turning another wheel of 48 teeth, the arbor of which is a tube fitting upon the other tube on the central arbor, and carries the hour-hand *x*. The tension of the main spring is adjusted in the first instance by the maker, who turns its arbor, on the head of which is fixed a ratchet *y*, in which a click takes and thereby holds it fast when wound up to the proper pitch; subsequently, when a watch is perceived to gain or lose time, it is regulated by strengthening or weakening the pendulum spring 1, *Fig.* 2, which will cause it to move quicker or slower. This adjustment of the pendulum spring is effected thus: the spring is fixed to a stud 2 upon the plate *e* by one end, and to the verge of the balance by the other; 3 is a lever lying betwixt the spring and the plate, and turning in a collar in the plate concentric with the centre of the balance, the verge of which passes through a hole in the lever; upon the lever is fixed a small stud 4 with a notch in it to receive the spring; the acting part of the spring is from 4 to the centre, therefore by turning the lever in either direction, the length of the spring is altered, and in order to regulate this length with precision, the arc through which the end of the lever can be made to traverse on the plate, is divided into a number of equal parts or degrees. In *Figs.* 1 and 3 are shown four pillars, by which the two plates of a watch are held together; and in *Fig.* 2, the heads of the same pillars are represented coming through the upper plate, with small pins put through them to keep the plate down.

Chronometers are portable time-keepers, in which, by the nature of the escapement, and the compensations for heat and cold, mean time is kept with sufficient accuracy to determine the longitude at sea. The relation between time and longitude, will be found explained under the head Longitude. As the principal differences between chronometers and other watches consist in the escapement and the balance, we shall not detain the reader with a description of the other parts of these machines, but shall proceed to describe more fully the various modes of constructing those grand essentials in all time-keepers, the regulator and escapement, noticing particularly those employed in chronometers.

Amongst the various steps by which horological machines were brought to their present state of perfection, the most important is the addition of the pendulum, which furnishes at once the most simple and accurate measure of time that we are yet acquainted with. Various claims have been made for the honour of this grand improvement, but the person to whom mankind is really indebted for bringing it into universal notice, is the celebrated Christian Huygens, of Zuylichem, who, in his excellent treatise *De Horologio Oscillatoreo*, has described the construction of a pendulum clock, and proved that he made one before the year 1658. His method of supporting the pendulum in the figure on the following page, in which a contrivance is resorted to for the purpose of insuring its isochronous motion, is ingenious, although it is not quite correct, as has been shown by Mr. Cummings, in his Treatise on Watch-Making. It consists of two cycloidal cheeks of brass, forming a curve, in which the

silk line by which the pendulum is suspended moves. When the art of clock-making had attained a high degree of perfection, and the application of this instrument to astronomical observations rendered the utmost accuracy desirable, it was soon perceived that the varying length of the pendulum rod, in consequence of its expansion by heat and contraction by cold, was a source of irregularity, which it was deemed difficult to overcome. To diminish as much as possible these variations, we are indebted to that eminent artist, George Graham, for the first application of the principle, which, under various modifications, has since been applied to preserve unchanged the centre of oscillation in a pendulum, and thus to insure the performance of all its vibrations in the same length of time. Those substances which were found to be least alterable by changes of temperature, such for example as wood, and particularly deal (pine), were employed in the best clocks. As the different metals are affected by heat in different degrees, Graham conceived the idea that the greater expansion of one might be employed to counteract the less expansion in another. After a series of trials, during a period of five or six years, he succeeded perfectly, by attaching to the pendulum rod a vessel containing mercury, which liquid, when the rod was expanded by heat, rose, from the same cause, in the vessel which contained it, so as to compensate for the downward expansion of the rod. This improvement was completed in the year 1721. Five years afterwards John Harrison, a carpenter in Barton, in Lincolnshire, subsequently so celebrated for his improvements in chronometers, invented and applied to a clock of his own manufacture the pendulum, which from its form is called the gridiron pendulum. In this the expansion of the iron rod is corrected by the greater expansion of rods of brass or of zinc, which tend to raise the bob in the same degree in which the expansion of the main rod tends to lower it, and it of course is retained in the same place: in this form the compensation pendulum is, to the present day, most commonly made. The principle upon which these pendulums were constructed has received various modifications in the hands of different artists; Harrison's rods, for example, instead of being arranged in the form of a gridiron, have been inclosed in a tube, and greater elegance and compactness, with a more easy mode of adjustment, have been attained; these, however, we believe, comprise the whole merit of the modern improvements.

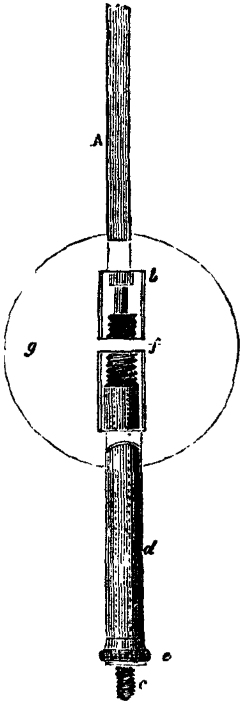




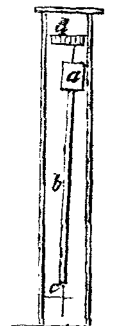
The annexed figure represents the mode of compensation proposed by Dr. Fearn. *a* is the pendulum rod suspended by a flexible spring, in the usual manner, from the cock *b*; *c* is a rod or bar of zinc attached to the back plate of the clock, by a screw at its lower end. The head *d* of this bar works upon a pin, which forms a joint, as represented in the drawing. Through this head there is a mortice, which allows one end of the lever *e e* to pass through it, and within which it may be fixed firmly by means of a tightening screw. The lever *e e* is attached to the clock-plate by a screw, which is also its fulcrum. Through a slit in the inner end of this lever the suspending spring passes, and is closely embraced by it on its lower side. The operation of this apparatus will readily be conceived; as the rod *a* lengthens by heat, or contracts by cold, the rod *c* will be similarly affected. The expansion of *c* will cause the inner end of the

lever to descend, and, consequently, to embrace the suspending spring at a lower point, and thus to diminish the effective length of the pendulum. The mode of adjustment is obvious, as a greater or lesser motion may be given to the lever, the upper end of the rod *c* being made to approach or recede from its fulcrum. To obtain the requisite accuracy, an adjusting screw may be made to act upon the head *d*.

In the year 1818 a reward was given to Mr. Reid for a compensation pendulum, in which the bob rested in a hollow cylinder of zinc, through which the rounded end *b c* of the steel pendulum rod is passed, the zinc itself being supported by the nut *e* at the end of the rod. As, therefore, the rod lengthened by heat, carrying the bob downward, so the upward expansion of the zinc raised the bob; and if the relative lengths of the steel and zinc were so proportioned that the amount of their expansions was equal, it is evident that the compensation above described would be perfect; but it is extremely difficult to effect this accurate proportioning of the lengths of the two metals. The length of the zinc at first must be such that its rate of expansion shall be in excess, and it must be cautiously reduced by repeated trials till the requisite accuracy is attained; this, however, is not done, except at a considerable expense of time and attention, to avoid which Mr. Reid has introduced the following modification. He forms a hollow screw in the cross bar *f* of the bob *g*, and an external screw on the same rake on the end of the zinc cylinder *d*; this latter is purposely made too long for due compensation, but its effective length may be commodiously and accurately reduced to what is required by screwing it up as represented in the figure; but after this has been done, supposing the nut *e* to have remained stationary, it is evident that the extent of gravity of the pendulum itself will have been lowered by the bob descending exactly as much as the upper end of the cylinder has advanced through the hole in the cross-bar *f*; an adjustment for time is therefore required after that for compensation has been effected, which is done in the usual way, by screwing up the nut *e*. This latter compensation, however, will not be required, if the rakes of the screws *f* and *c* are proportionate to each other, as the weight of the bob alone is the sum of the weights of the bob, the zinc cylinder, and the nut. Thus, if the former weight be assumed as ten, and the latter as eleven, the screw at *f* must have ten threads, in the same length that the screw at *c* has eleven threads. Care must be taken in screwing the cylinder of zinc up or down, to place the finger and thumb at the same time on the nut, so that the two may turn together; or the nut may be fastened to the cylinder.



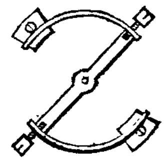
In connexion with this branch of the subject, we may notice the inverted spring pendulum, invented by Mr. W. Hardy, of Wood-street, Clerkenwell. The object of this invention is to ascertain the stability of the support of clocks, for which purpose the weight at its upper extremity is screwed down until it will perform its vibrations in the same period of time as the pendulum of the clock. The inventor states that when the weight *a* is screwed up to the top of the steel rod *b*, it vibrates only once or twice in eight or nine seconds, which renders it remarkably susceptible, and that its sensibility is



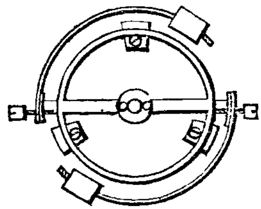
so great that the attraction of the sun and moon, or of mountains, may be observed by it: it serves also for ascertaining the stability of buildings. *a* is the weight screwed upon a steel rod *b*, which is supported at bottom by a small piece of steel watch-spring *c*, and contained in a glass tube; *d* is a cap or stopper to the upper end of the tube, and carrying underneath a small graduated scale, over which ranges the index at the top of the weight. For this invention Mr. Hardy received a reward from the Society of Arts. His communication to them was accompanied by testimonials to the value of the invention from several eminent scientific characters, amongst whom was Captain Kater, who employed the instrument to assure himself of the stability and freedom from tremor of the base upon which his clock rested during his experiments.

Before the application of the pendulum as a regulator in clocks, balances had been employed for that purpose, but were quickly superseded after the introduction of the pendulum; but as external motion is destructive of the regularity of the pendulum's performance, the balance was still the only regulator which could be applied in portable machines, and the great improvement made in that regulator by the addition of a spring has caused it to approach the pendulum in point of correctness. The first invention attaching a spring to give to the balance, by its elasticity, a power which renders the action of this sort of regulator similar to that of gravity in a pendulum, is undoubtedly due to Dr. Hooke, but he appears to have applied it only in a straight form. Huygens, improving upon this idea, substituted a spiral spring, which is much more favourable to the vibrations of the balance.

The alterations to which the length of the pendulum is exposed by variations of temperature, and which affect the going of clocks, have already been noticed; but watches with a balance are still more exposed to irregularity from that cause, as not only the balance expands or contracts according to the rise or fall of the thermometer, but the regulating spring itself suffers the same changes. As the balance contracts, and its diameter becomes less, it will be more easily carried round by the vibrating forces, and will then vibrate more quickly; and as the spring attached to the balance becomes contracted at the same time, it will likewise act with greater force when cold, and on this account the vibrations will be farther quickened. There are two ways of correcting these irregularities; the first, which was invented by Harrison, consists in lengthening or shortening the spring when heat or cold may have given it more or less force; the other method is to cause the balance to expand instead of contracting by cold, by which means the spring, when in the state of great rigidity, has more work to do; this method originated with Peter Leroy, and has since been carried to great perfection by Arnold. Harrison (whose application of the different expansion of two metals to correct the variations in the length of the pendulum, has been already noticed), applied the principle in a manner not before thought of, and made it act on the spiral spring so as to produce the desired compensation in the regulator. His method is described as follows, (*Principles of Mr. Harrison's Time-keeper*, p. xii—Notes.) "The thermometer kirb is composed of two thin plates of brass and steel, rivetted together in several places, which, by the greater expansion of brass than steel by heat and contraction by cold, becomes convex on the brass side in hot weather, and convex on the steel side in cold weather; whence, one end being fixed, the other end obtains a motion corresponding with the changes of heat and cold, and the two pins at the end, between which the balance spring passes, and which it alternately touches as the spring bends and unbends itself, will shorten or lengthen the spring, as the change of heat or cold would otherwise require to be done by hand in the manner used for regulating a common watch." This method of effecting the compensation, although it evinces considerable ingenuity, is now seldom used, owing to the extreme difficulty of effecting an accurate adjustment; recourse is therefore had to the principle introduced by P. Leroy, a modification of which is seen in the figure on the following page, which represents the balance of a chronometer as commonly constructed. A circular groove is turned in the flat face of a piece of steel, and into this groove



a piece of good brass is driven, and a little of the solution of borax is applied to prevent oxydation. This compound piece being then put into a crucible, is made sufficiently hot to melt the brass, which in these circumstances adheres firmly to the steel without requiring any solder. The face of the steel is then cleaned, and by proper application of the mechanical means of turning, boring, and filing, the superfluous steel is taken away, and the balance is left, consisting of two, or sometimes three, radii, and a rim, the external part of which is of brass, and the internal part of steel, the former metal being about twice the thickness of the latter. In this state the arms of the rim are then cut through and diminished in their length, as in the figure; and near that extremity of each arc which is farthest from its radius, is put on a piece or weight, which can be slided along the arm, so as to be adjusted at that distance which shall be found, upon trial, to produce a good performance under the different changes of temperature; the flexure of the arms by the change of temperature carrying the weights nearer to the centre in hot than in cold weather, and the more the greater the distance of the weights from the radius. The small screws near the ends of the radii afford an adjustment for time, as the balance will vibrate more quickly the further these are screwed in; and the contrary will be the case if they be unscrewed or drawn further out.



The accompanying cut shows a balance according to the construction of Arnold, and specified by him to the commissioners of longitude. The expansion weights are cylindrical, and are adjusted upon the arms by screwing; and there is an inner rim, upon which three weights are adjusted by sliding, which serve to regulate the going of the time-piece in different positions. The necessity of a different adjustment of the balance, according as the balance is to vibrate with its axis vertical to the horizon, or parallel to it, will be obvious when we consider that the pivots of the axis bear very differently according to the position of the chronometer; and it requires some management to make the frictions the same, whether the axis be turning upon one of its ends, or upon the two cylindrical faces of the pivots; and still more than this, since the balance itself has a permanent figure compared with the spring, which, in every part of its vibration, alters its distance from the axis, and in every part of its length has a different degree of rotatory motion; it cannot be expected, nor does it happen, that a balance, which is found to be in poize along with its spring when out of the chronometer, will make equal vibrations, as to time, in all positions when in its place; and in addition to these difficulties, there is one part of the vibration where the force of the spring and the inertia of the balance are not simply in opposition to each other, but are combined with the maintaining power, viz. during the action of the escape. The remedy for all these difficulties, which is happily adopted in chronometers for use at sea, is to place the axis in a vertical position, by which means the balance itself is not affected by gravity; but for pocket timepieces, the ingenuity of the artist is called upon for expedients of which it would not be easy to exhibit a complete theory. The general principle commonly used, is to consider the balance, when out of adjustment for position, as a pendulum when above and below the centre of suspension, acted upon by gravity, and, at the same time, urged to a quiescent point by the force of elasticity. In these circumstances the vibrations will be quickest when the point of stable equilibrium is downward, and they will be slowest in the opposite positions of the machine. This leads to the remedy of diminishing either the radius or the weight on that side which is lowest when the rate is most quick. Thus, if one of the two adjusting screws in the first of the preceding balances were downwards in the position of quickest rate, that screw would require to

be screwed a very little quantity inwards, and the opposite screw to be screwed a like quantity outwards, in order to remedy this imperfection without much alteration of the other adjustments. And if a like imperfection were found in the vibrations of the balance when tried in a vertical position, having the lowest point at rest in a line at right angles to a line passing through the radii, a similar alteration must be made in the expansion weights, either by a careful flexure of the circular arcs, or by altering the quantities of those weights; or else by means of small circular screws tapped into the weights themselves, and directed towards the centre like the weights at the extremities of the radii. By these, and other correspondent means, the balance may be made to keep time in all those positions wherein its plane shall be perpendicular to the horizon; but even in these trials very great pains and labour may be required to produce a high degree of accuracy; and, after all, as the quantity of action in the spring must alter the quantity of pendulous effect in this curious and delicate time measurer, it may be doubted whether the adjustments for position in the vertical balance can be effectual any longer than while the arcs of vibration remain the same. This consideration points to the necessity of an adjustment in the maintaining power, in order that the vibrations shall not fall off; the means of effecting this will be shown in treating of the different sorts of escapements, to the consideration of which we shall now proceed.

The escapement is a general term for the manner of communicating the motion of the wheels to the pendulum of clocks or balance of watches. One of the most ancient escapements is that which is now applied in almost all common pocket watches: it is represented in *Fig.* 1, and is best suited to the long vibrations of the balance, which was invented earlier than the pendulum. *a b* denotes the rim of a contrate wheel, called the crown wheel, having its teeth pointed and sloped on one side only, so that the points advance before any other part of the teeth during the motion. *c* and *d* are two pallets or flaps, proceeding downwards from the verge *e f*. The pallets are nearly at right angles to each other; and when the balance *f g*, fixed on the verge, is at rest, the pallets remain inclined to the plane of the wheel, in an angle of about forty-five degrees; but when it is made to vibrate, one of the pallets is brought nearer to the perpendicular position, while the other becomes more nearly parallel. The wheel must be supposed to have one of its teeth resting against a pallet by virtue of the maintaining power. This tooth will slip off or escape as the pallet rises toward the horizontal position, at which instant a tooth on the opposite side of the wheel will strike against the other pallet which is down. The returning vibration, by raising this last pallet, will suffer that tooth to escape, and another tooth will apply itself to the first-mentioned pallet. By this alternation, the crown wheel will advance the quantity of half a tooth each vibration, and the balance or pendulum will be prevented from coming to rest, because the impulse of the teeth against the pallets will be equal to the resistances from friction, and the reaction of the air. This escapement not being adapted to such vibrations as are performed through arcs of a few degrees only, another construction has been made, which has been in constant use in clocks for this century past, with a long pendulum beating seconds. *Fig.* 2, on the next page, *a b* represents a vertical wheel, called the swing wheel, having thirty teeth. *c d* represents a pair of pallets connected together, and movable, in conjunction with the pendulum, on the centre of axis *f*. One tooth of the wheel in the present position rests on the inclined surface of the inner part of the pallet *c*, upon which its disposition to slide tends to throw the point of the pallet further from the centre of the wheel, and consequently assists the vibration in that direction. While the pallet *c* moves outwards, and the wheel advances, the point of the pallet *d*, of course, approaches towards the centre, in the opening

Fig. 1.

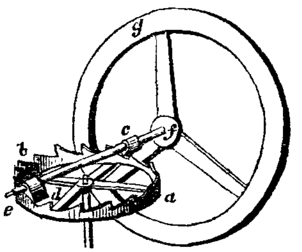
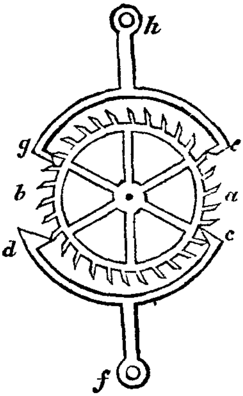
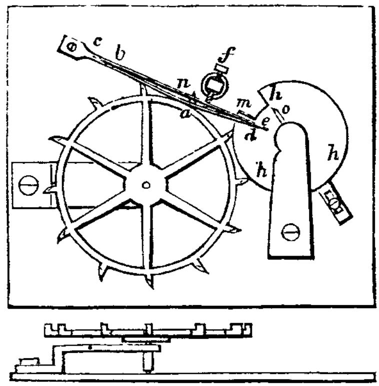


Fig. 2.



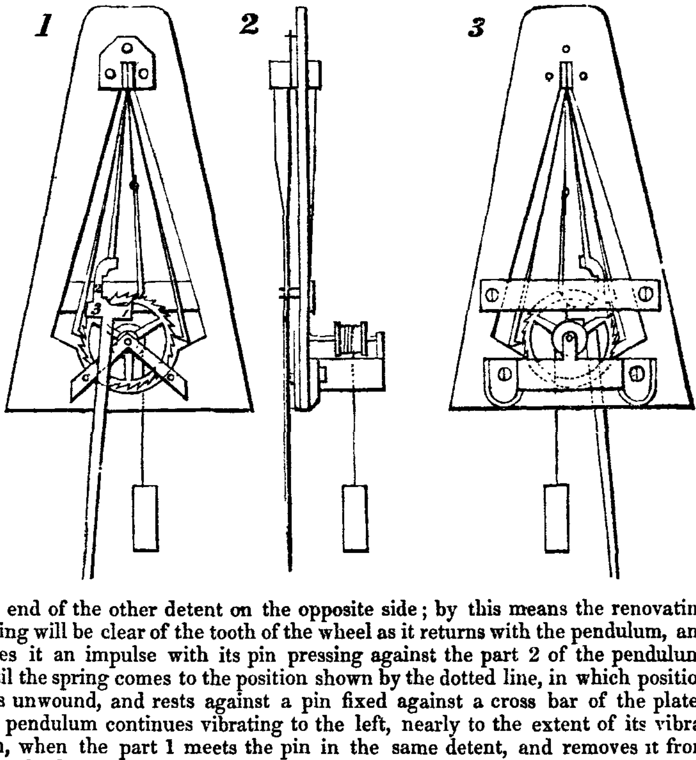
between the two nearest teeth; and when the acting tooth of the wheel slips off, or escapes from the pallet *c*, another tooth on the opposite side immediately falls on the exterior inclined face of *d*, and by a similar operation tends to push that pallet from the centre. The returning vibration is thus assisted by the wheel, while the pallet moves towards the centre, and receives the succeeding tooth of the wheel after the escape from the point of *d*. In this manner the alteration may be conceived to go on without limit. The celebrated George Graham improved this escapement very much, by taking off part of the slope furthest from the points of the pallets; instead of which part he formed a circular or cylindrical face, having its axis in the centre of motion. Pallets of this kind are seen on the opposite side of the wheel at *e* and *g*, having *h* for their centre or axis. A tooth of the wheel is seen resting upon the circular inner surface of the pallet *g*, which is not therefore affected by the wheel, excepting so far as its motion, arising from any other cause, may be affected by the friction of the tooth. If the vibration of the pendulum be supposed to carry *g* outwards, the sloped surface will be brought to the point of the tooth, which will slide along it and urge the pallet outwards during this sliding action. When the tooth has fallen from the point of this pallet, an opposite tooth will be received on the circular surface of *e*, and will not affect the vibration, excepting when the slope surface of *e* is carried out so as to suffer the tooth to slide along it. In the two former escapements, there is always a certain portion of vibration takes place after the drop which drives the pallet back, and causes the index also to recede through a small arc: this has been distinguished by the name of a recoil. The escapement of Graham, and all such as have no recoil, have been called dead beat escapements, because the index for seconds falls directly through its arc, and remains motionless on the line of division till the next vibration. It may be observed, that the maintaining power in Graham's escapement, may be applied during a small portion only of the vibration; and that an increase of the maintaining power tends to enlarge the arc of vibration, but scarcely interferes with its velocity. In the escapements just described, the escape wheel is in continual contact with the pallets belonging to the axis of the balance, and the friction arising from this circumstance may be considered as a principal cause of the irregularity in the going of watches. If we suppose a regulator to be made so perfect as to be perfectly isochronal, while vibrating in a free position, that advantage would be diminished, or lost, as soon as it was placed in connexion with a train of wheels; and the errors would be more or less, according to the nature and quantity of friction in the escapement. It would be, therefore, extremely useful to secure to the regulator a perfect liberty of vibration, except during the short intervals of time which may be necessary for the action of the escape wheel, to give it a new impulse. This ingenious idea was first started, and also carried into execution by P. Leroy, who in 1748 presented to the Academy of Sciences in Paris a model of a detached escapement, the effect or action of which may be briefly described as follows: an escape wheel is kept in repose by a lever detent; the balance unlocks the detent, and receives an impulse or stroke on a pallet through a part of every second vibration, and during great part of its course it is free and detached. A great variety of escapements have been contrived by various ingenious men; those in which springs are used in the locking pieces instead of pivots are at present generally preferred; we shall, therefore, proceed to describe the escapement of Mr. Arnold, who we believe is the author of this improvement. The engraving on the next page is a representation of this escapement. The teeth of the escape wheel are of a cycloidal shape, in the face part, which is intended for

action, the sections of which, with those of the two other sides, form a sort of mixed triangle. *b b d* represents the detent, which is formed of a flexible piece or spring, bending between *c* and *n;* and in the part *n b d,* which is stronger than the other, is fixed the locking pallet *a,* opposite an adjusting screw *f.* The pallet projecting below the spring detent locks upon the interior angle of the tooth, suspending the motion of the escape wheel, and leaving the balance to vibrate free, as pointed out in the preceding escapements. The action of the spring detent (for the joint of the detent is itself a spring) presses the locking pallet against the screw *f,* except at the time of unlocking the wheel. A very delicate spring *n e,* called the discharging, or unlocking spring, (and also the tender spring,) is attached by one end *n* to the spring detent *c b n b a;* and passing under the adjusting screw *f,* extends a little beyond the extremity *d,* by the detent itself; *h h h* is a circular piece attached to the axis of the balance, and *o* the discharging pallet.



This pallet when the balance is in motion from *e* to *d* presses against the end of the discharging spring *n e*; and carrying it together with the locking spring *b b d* disengages the locking piece *a* out of the internal angle of the tooth, with which it was in contact; and the escape wheel then communicates a new power to the balance by its impulse on a pallet *m,* which is fixed or set in the aperture of the circular piece. As soon as this is done, the spring detent, or locking spring, falls back to its position against the adjusting screw *f;* and the pallet, by receiving or intercepting the next tooth, stops the motion of the escape wheel. When the balance returns from *d* to *e,* the unlocking pallet acts again on the extremity of the discharging spring, but this being very delicate, gives way without disturbing the detent, or locking spring; and the balance, after suffering a trifling degree of resistance by that contact, continues its free vibrations. At the next vibration the unlocking takes place, and the action of the escapement proceeds successively, as explained before. The detached escapement was applied first to chronometers or time-pieces, but is now also used for astronomical clocks; and various excellent constructions have been invented by different artists, amongst which we may mention those of Hardy and Reid. In 1812, Mr. Prior, jun. was rewarded by the Society of Arts for the construction of a detached remontoire escapement for clocks, which possesses considerable merit. The advantages of this escapement consist in the freedom of its parts from friction; in the exact and equal impulse which it will continue to give to the pendulum, unaffected by the clogging of oil and increased friction of the train; and in the small power required for restoring the tension of the remontoire spring, which does not require to be wound up quick, or to be pushed beyond any catch or spring to keep it in its proper situation. The engravings on page 696, with the following description extracted from the *Transactions of the Society,* will explain the construction. The swing-wheel, *Figs.* 1 and 3, has thirty teeth cut in its periphery, and is constantly urged forwards by the maintaining power which is supplied by the small weight; two spring detents are used to catch the teeth of the wheel alternately; these are, at the proper intervals, unlocked by the parts marked 1 and 3 upon the pendulum rod, intercepting two small pins projecting from the detents, as it vibrates towards the one or the other; the renovating or remontoire spring is fixed to the same stud as the detents; it is wound up by the highest tooth of the wheel, as seen in *Fig.* 1, (its position when unwound being shown by the dotted lines.) This being the case, suppose a tooth of the wheel is caught by

one of the detents, this prevents the wheel from moving any further, and keeps the renovating spring from escaping off the point of the tooth; in this position, the pendulum is quite detached from the wheel; now, if the pendulum be caused to vibrate to the right, the part of it marked 2 comes against the upper pin, seen in *Fig.* 2, projecting from the renovating spring, and pushes this spring from the point of the wheel's tooth; on vibrating a little further, the pendulum removes the detent which detained the wheel, by the part 3 striking the lower pin, *Fig.* 2, which projects from the detent; the maintaining power of the clock causes the wheel, thus unlocked, to advance until detained by a tooth resting upon



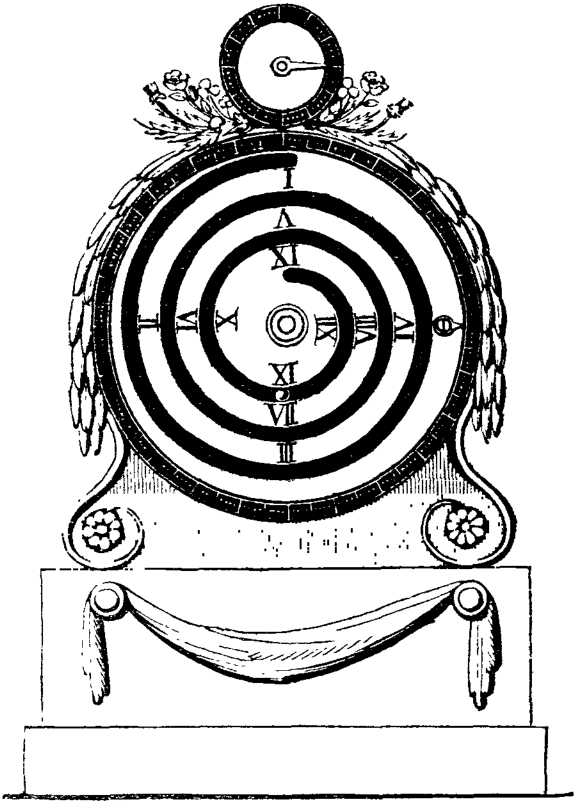
the end of the other detent on the opposite side; by this means the renovating spring will be clear of the tooth of the wheel as it returns with the pendulum, and gives it an impulse with its pin pressing against the part 2 of the pendulum, until the spring comes to the position shown by the dotted line, in which position it is unwound, and rests against a pin fixed against a cross bar of the plate; the pendulum continues vibrating to the left, nearly to the extent of its vibration, when the part 1 meets the pin in the same detent, and removes it from the wheel, and unlocks it; the maintaining power now carries it forward, pushing the renovating spring before it until another tooth is caught by the first detent, which detains the wheel in the position first described, the renovating spring being wound up ready to give another impulse to the pendulum. The pin is not fixed to the renovating spring itself, but is part of a piece of brass, which is screwed fast to the renovating spring, and is made very slender near the screw which fastens it; this permits the renovating spring to give way, if, by the weight being taken off the clock, or any other accident, the escape wheel should be wound backwards, so as to catch on the detents improperly. The weight in the preceding figures merely represents the means by which the escape wheel was put in motion in the model presented to the Society, which consisted merely of the escapement; but when attached to a clock, the remontoire spring is wound up by the maintaining power of the clock transmitted to the escape wheel by means of the train.

Chronometers and clocks for astronomical purposes, in which extraordinary nicety in the exact measurement of time is necessary, have, besides the compensation pendulums or balances, and detached escapements, before described

jewelled pallets, and all their pivot-holes jewelled: they are likewise provided with a contrivance for continuing their motion during the time of winding up, when the action of the maintaining power is suspended. For this purpose a second larger ratchet wheel is added on the same arbor which admits the clock to be wound up, but with teeth pointing the contrary way; a strong spring, usually the greatest portion of a circle, connects this large ratchet wheel with the great wheel of the clock, which is on the same axis with it, one end of this spring being attached to the great wheel, and the other to the large ratchet; and a catch proceeds from the inner face of this back plate to the teeth of this ratchet, which prevents its moving back when the clock is winding up, and serves as a support for the reaction of the maintaining spring. When the clock is left to the action of the weight, the small ratchet turns round the larger one, and contracts or coils up the spring till it has strength sufficient to impel the great wheel and train; and when the action of the weight is suspended, as in winding up, the spring, freed from the contracting power of the weight, expands itself and forces round the great wheel, its action in the contrary direction on the great ratchet being prevented by the catch before mentioned. Leroy is considered to be the inventor of the spring impeller to prevent loss of time in winding up, but the idea of continuing the motion of the train during this time originated with Huygens, for he contrived a method by which the weight of his clock should continue to act on his train whilst it was drawing up; the weight in his clock having been made to draw up in a similar manner to that used in common wooden clocks, instead of being wound up as in our metallic clocks.

What has been already advanced, will, we trust, be sufficient to convey a clear idea of the nature and general construction of horological machines; but great diversities in their form and a variety of curious movements have been introduced by the taste and ingenuity of artists in this branch: some of these excite admiration by the number and intricacy of the component parts, and the admirable precision with which they act, whilst others evince equal ingenuity by the simplicity of the means adopted to obtain the end proposed. Of this last description of clocks, none have as yet exceeded that invented by the celebrated Dr. Franklin; it shows the hours, minutes, and seconds, and yet contains but three wheels and two pinions in the whole movement. The lowest wheel contains 160 teeth, and goes round once in four hours; it carries the hand on its axle, which points out both the hours and the minutes, as will be described, and it turns a pallet above it of 10 leaves, on the same axis with which is a wheel of 120 teeth, that gives motion to a pallet of 8 leaves: the second-hand is annexed to the same axis with this latter pallet, as also the swing-wheel, which carries 30 teeth, that gives motion to the pallets of an anchor escapement, and to its pendulum that vibrates seconds. The dial of this clock is of singular formation; the external circle on it contains 240 divisions, numbered from 1 to 60, in four successive notations; this circle shows the minutes; within it the hours are arranged in three concentric circles, or in a volute of three revolutions along four radii, which form right angles with each other. By this arrangement, while the point of the hand shows the minute, its side exhibits the hour; or, more strictly speaking, shows that the hour is one of three; but so that it will hardly ever happen that any doubt will remain of which it may be, as there are four hours difference between the figures next to each other on the same radial line. A small circle is placed above the great one, and divided into 60 parts for the seconds. This clock was wound up by a line going over a pulley and ratchet, on the axis of the great wheel, by which the weight was drawn up in the same manner as in the common wooden clocks. Many of these clocks have been made which are found to measure time exceedingly well. The small imperfection in this clock, of its leaving the uncertainty mentioned as to which of three hours it denotes, though so easily corrected by the judgment, has given rise to some ingenious contrivances to obviate it. Of these the most curious is that which forms the subject of the engraving on page 698. To the great wheel of this clock two concentric plates are annexed, the external one of which has a groove cut through it along the line of a volute of three

revolutions. This groove forms a trough, in which a metal ball is placed, part of which is seen through the excavation beneath the hour 11 in the figure; as the plate and groove turn round, the ball rolls along the volute, still approaching nearer the centre as it proceeds; and when it at last arrives at the centre, it falls into another trough, by which it is again conveyed to the external part of the volute. The hours are engraved between the revolutions of the volute,



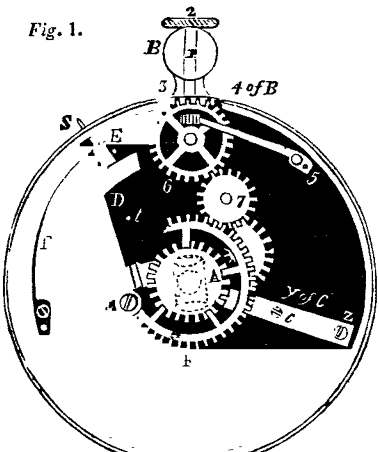
and the minutes are marked in four divisions of 60 each, upon an external fixed circle, to which an index annexed to the volute plate points. Several of these clocks were to be seen in the watchmaker's shops in London some years ago, but we believe the author of this ingenious contrivance is unknown.

In addition to the parts which measure and register time, and therefore alone constitute a watch or clock, various appendages are at times connected with them for pleasure or convenience, as chimes and puppets to clocks, musical and repeating movements, &c. to watches; but as these are not strictly comprised under the head of horology, we shall merely notice one or two inventions of this class, our limits not allowing us to do more.

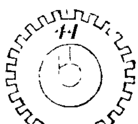
One very useful addition which is frequently made to clocks and watches, is the alarum, or contrivance for calling attention at any fixed period of time. An excellent arrangement of this kind is the *patent detached alarum watch,* invented by Mr. Berollas, of the City Road, which is an improvement upon a former invention of the same gentleman called the *warning watch.* In the present invention all the useful parts of the watch are retained, while those that were inconvenient or had a tendency to disturb its regular movements are here in a detached state. The advantages that result from this arrangement are, first,

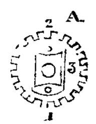
the applicability or adaptation of the invention to all kinds of watches, whatever may be the principles of their construction; second, the alarum being detached from the watch, it can be made to produce a noise sufficiently loud for a house alarum; third, alarum watches as before constructed were inconvenient, from their bulk, to wear—by this contrivance they may be made as flat and thin as may be desired; and, lastly, the expense is much less than any watches hitherto made of similar performance. *Fig.* 1 represents the mechanism attached to the watch, by which the alarum is locked and unlocked, as it appears when the dial-plate is removed. The index by which the alarum is set to the proper time of going off, is attached to a hollow axle fitted upon the arbor of the ordinary hour-wheel. This index may be set by hand; but a preferable method is to attach a toothed wheel 4, which works into an intermediate wheel 7, which works into the wheel 6, and this latter works into a wheel 3, fixed at right angles to it upon the square end of the steel arbor 1, which runs through the pendant, and has at its other extremity a milled nut 2, by turning which nut it is obvious that motion will be conveyed to the alarum wheel and index to set it at any particular hour. To prevent the train being turned the wrong way,

Fig. 1.

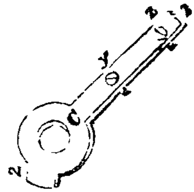


and to retain the index in its place, a small ratchet wheel is fixed upon the square part of the steel arbor 1, into which ratchet a spring-pall 5 falls. The hollow axis of the alarum index is made of steel, and on its underside is formed into a flat circular plate, as at 44, which represents the reverse side of the wheel 4; and in this plate a notch is cut straight down on one side, and sloping on the other, as shown at 45, which is a section of the wheel and hollow axle, the straight side of the notch lies in the direction of a radius of the flat plate in 44. The hour-wheel, marked A, *Fig.* 2, lies immediately underneath the alarum wheel, and has on its under side an oblong steel plate, 1, 2, 3, in the detached figure A of *Fig.* 2, which is called the detent. The detent is spring-tempered, has a hole in its centre for the free passage of the cannon arbor, and is fixed flat upon the hour-wheel by a small screw and steady pin at 2; into the opposite end of the detent plate at 1, is rivetted a small pin of sufficient length to pass through a hole in the hour-wheel, and to project beyond the upper surface of the same in such manner, that when the hour-wheel and the alarum-wheel are put together in their right places, and this pin presses upon the flat surface of the steel plate 44, the end 1 of the detent is depressed below the under face of the hour-wheel, but when it comes over the notch it falls into the same, and allows the end of the





detent to rise and lie flat in the recess in the hour-wheel. The end 1 of the detent acts upon the circular end 2 of a flat steel spring C, *Fig.* 1, and shown det ·hed in the following page; it is called the elevator, and is fixed in its place by the screw and steady-pin at Z, which end is thicker than the other parts of the spring, so that the end 2 is raised above the plate on which it is fixed; the degree of elevation may be adjusted by turning the screw-top at *y*,



which works freely through a hole in the elevator. The end 1 of the detent presses upon the elevator in such manner, that whilst the detent is depressed it holds down the end 2 of the elevator; but so soon as the pin in the detent enters the notch, and the detent rises, the pressure is withdrawn from the elevator, and it likewise rises to discharge the alarum, which it does through the medium of another piece called the propeller, drawn in its proper place and form at D, *Fig.* 1, and also shown in the detached figure in the margin. It is a steel lever without spring, and turning upon the screw x as a fulcrum; it has a projecting piece W, which is formed into an inclined plane, and highly polished and hardened; this inclined plane falls directly under the end 2 of the elevator C, also polished at this part; consequently, whenever the elevator is depressed by the detent, its end 2 will press upon the inclined plane W of the propeller, and drive its end V outwards; this end is formed into a portion of a circle not concentric with x, and presses against the locker E, *Fig.* 1, which is a cylindrical piece of steel, having in its outer end a small pin s projecting through the case of the watch; the locker E moves between two pins, and is pressed against the end of the propeller D by the spring F, and kept at all times in contact with it. The combined effect of the several parts may be briefly recapitulated as follows:—whilst the detent is depressed, it presses down the circular end of the elevator c, which acting upon the inclined plane W of the propeller D, forces its circular end against the locker E, and causes its small pin s to protrude beyond the case, in which state it will remain until, by the revolution of the hour-hand, the pin in the detent falls into the notch on the alarum arbor; when the elevator rises, and the pressure being withdrawn from the inclined plane of the propeller, the locker E is pushed in by the spring F, and remains in that position until the sloping side of the notch 44 has been moved round sufficiently to depress the detent spring again. The above is all that is necessary to form the union between the going parts of any watch, and a detached alarum, because it will be evident that such alarum may be disengaged or set off by the sudden withdrawal of the locker; we shall therefore proceed to describe the manner in which the alarum movement is operated upon, whether the alarum of the bell, rattle, or any other kind.

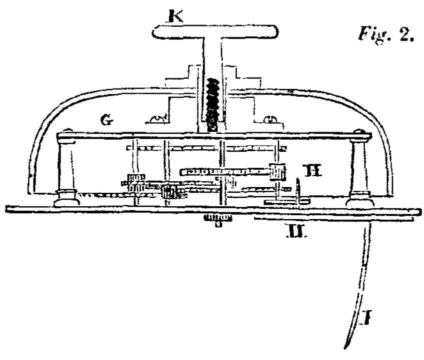


Fig. 2.

An alarum movement in its separate state is represented at G H, in the annexed figure, and consists of a frame, the upper plate of which is nearly half an inch less than the pillar plate, in order that the works may be covered by, and contained within the bell, as shown at *Fig.* 2, which is a section or profile of the alarum movement. A going barrel, which contains the mainspring, is placed in the centre of the *said frame*, and a steel wheel cut with ratchet teeth to work the hammer is fixed on the upper part of the said barrel, its other side carrying the main wheel to drive the train, which generally consists of three wheels and four pinions. The alarum hammer has a spring and a regulating spring on the opposite side of the plate as shown at K, *Fig.* 4. The fly pinion has an arm of steel fixed on its arbor, and as this comes in contact with the projecting pin,

the works are locked, and the alarum prevented from running down: but so soon as the pin H is moved, the whole is at liberty, and free to move; the pin H passes through a hole in the plate, and rises from the locking lever H on the other side of the plate, as shown in *Fig.* 4, where it may be seen that this locking lever turns on a screw pivot at its inner end, and is constantly pressed to one side by the force of the spring P, which operates in such a direction as to throw the pin out of contact with the steel arm of the fly arbor, and consequently always keeps the alarum work in a free state for motion; but it may be locked at any time by pushing the locking lever H, *Fig.* 4, backwards, or against the action of its spring P; a wire tail, I, rises perpendicularly out of the outer end of the locking lever H, and it is this wire tail that is to be engaged with the small end *s* of the locker E *s*, *Fig.* 1, whenever the alarum is to be wound up and set. This locking lever H, with its two pins, is here shown in a detached state.

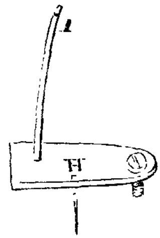
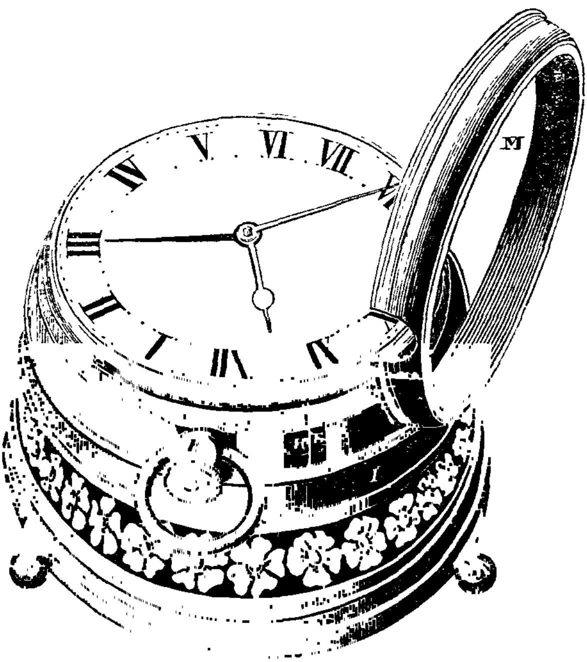


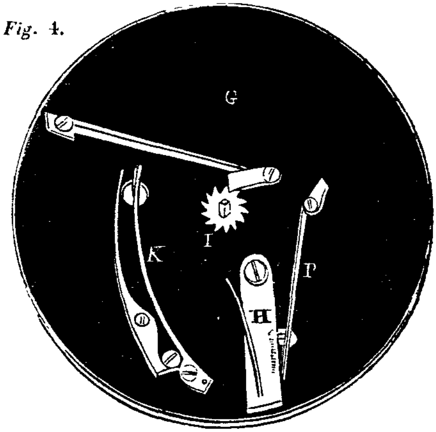
Fig. 5 shows a watch having all the above described parts appertaining thereto, and placed upon one of the aforesaid detached alarum movements; I being the case of the alarum, formed of open-work, chased or otherwise



ornamented, and having the appearance, when empty, of the ordinary receptacle of an external watch case; M being the usual rim that shuts down over the watch with a spring catch, and thereby holds it steadily in its proper position; the alarum movement is fixed in this external case, with the pillar plate upwards, and the works and bell downward; consequently, the wire tail I, *Fig.* 4, projects upwards into the case, and in placing the watch within, it is necessary to observe that the projecting end of the locker *s*, *Fig.* 1, comes behind, and engages with this wire tail, as seen at H F, *Fig.* 5, in such manner, that it may push back the locking lever, H, *Fig.* 4, and thereby lock the train of the alarum when the rim M is to be shut down, and the alarum hand set as aforesaid

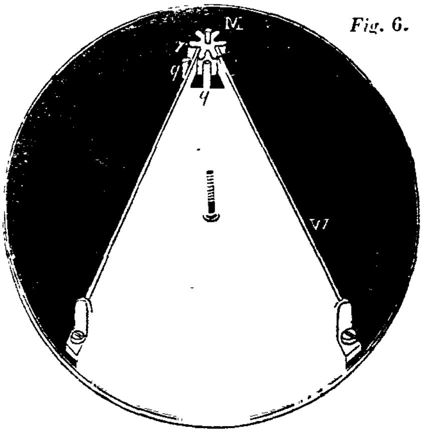
to the time upon the dial when it is to be discharged. The alarum may then be wound up by the key, or milled head K, *Fig.* 2, which is screwed upon the main spring arbor, so that it can only turn it in one direction without unscrewing, and the machine will be ready to operate; because at the assigned hour and minute, the ends of the locker will be withdrawn into the watch, thereby releasing the wire tail I, and the locking lever H, *Fig.* 4, by which the alarum will be discharged, and will instantly run down.

Fig. 4.



What has been said of the bell alarum movement, equally applies to rattle movements, because they consist of the same parts, and are constructed and used in the same manner, except only that the bell, the hammer, and the steel ratchet wheel for working the same, and the springs connected therewith, are dispensed with, and in lieu thereof, the rattle movement, shown in *Fig.* 6, is substituted. This consists of two strong steel wheels N N, so fixed or screwed upon the outside of the upper plate that they may both press in the same direction against the two strong pins or studs $q\,q$ to receive them, and the upper plate may in this construction be made of the same diameter as the lower plate, because there is no bell to go over it. A coarse steel pinion M is fixed on to a square upon the continued arbor of the first wheel in the movement, and which wheel for this purpose is brought nearer to the edge of the plate, in such manner that the lever of the said pinion may engage with the ends of both the springs N N, and by its revolution may carry them some distance towards r, and on their return they strike against the pins $q\,q$, and produce a powerful rattling noise; more or less springs may of course be used for a similar purpose, according to the extent of noise required.

Fig. 6.



Of late years, the ingenuity of watch-makers has been much exercised in the winding up of watches, without the employment of detached keys; but from the difficulty of applying such an improvement to watches having fusees, their efforts have been solely directed to the winding up of those having *going-barrels;* and various contrivances have been proposed and adapted to the latter for that purpose. Mr. Berollas, whose patent detached alarum watch we have just been describing, has, however, overcome all the obstacles which the subject opposed to him, and has contrived the means of winding up watches of both construction without keys, by a contrivance exhibiting great simplicity as well as ingenuity. For this invention he has taken out a patent, and from the specification of it we make the following extracts; which, together with the

annexed engraved figures, will give the reader a full insight into the arrangement and the mode of constructing this useful improvement. "The first mover, or power, in most horological works, is obtained either by the action of a weight or spring. In pocket watches, the power is obtained by a spring called the main spring, which is enclosed in a box called the barrel. Now there are two distinct ways of applying the power of this main spring to the first wheel of a watch; one of them consists in the intervention or agency of a fusee, which is put upon the first wheel; in the other, the first wheel is put upon the barrel itself that contains the spring, which arrangement is distinguished from that having a fusee by the term 'going-barrel.' Watches having going-barrels are wound up by turning round the barrel arbors; and watches having fusees, by the fusee arbors. My invention consists in a new mechanical arrangement, applicable to the winding up of horological works. First, as respects what is termed a going-barrel, the following are the contrivances that I have invented as applicable thereto: *Fig.* 1 represents a watch with a going-barrel, to which my invention is applied; in which figure a part of the dial-plate is represented as broken away, for showing the novel parts, the operation

Fig. 7.

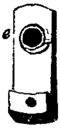


Fig. 1.

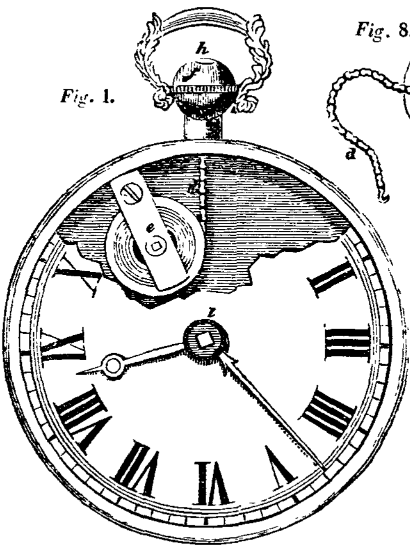


Fig. 8.

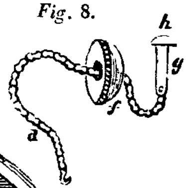


Fig. 2.

Fig. 3.

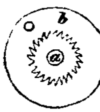


Fig. 4.

Fig. 5.

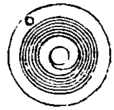


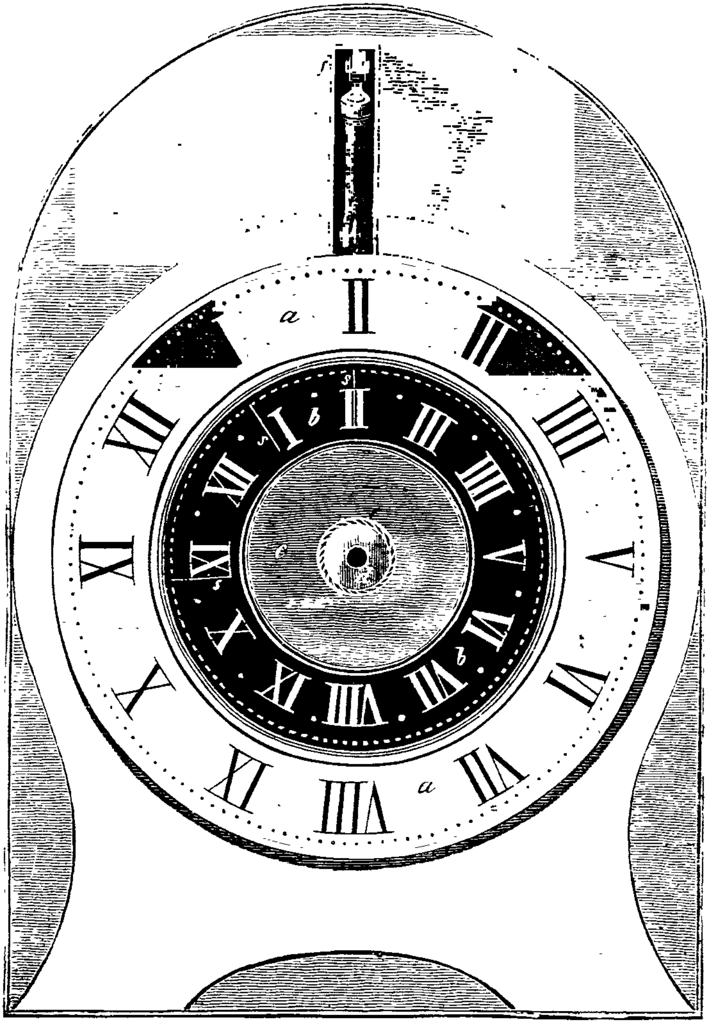
Fig. 6.

of which will be understood by first describing the separate figures, 2, 3, 4, 5, 6, 7, 8, all the same letters of reference in which refer to similar parts. *Fig.* 2 is the barrel ratchet with its click and spring, which keeps the maintaining power up; this ratchet is put on the barrel arbor, which is squared, and the plate is sunk in which it lays—it is on the side of that part of the plate under the dial; this barrel ratchet is sunk or turned out as far as the teeth to receive another ratchet with its click and spring, shown at *a*, *Fig.* 3, which I call the recoiling ratchet. This recoiling ratchet is fastened on to the barrel pulley 6; the upper side of this barrel pulley is sunk to receive a spring, shown in *Figs.* 1 and 5, which is the recoiling spring; on the edge of the barrel pulley there is a groove to receive a chain *d*, shown at *Figs.* 1 and 8, which is hooked on a

pin in the said groove. *Fig.* 7 gives a perspective view of the stud which keeps the barrel pulley steady and close to the barrel ratchet; the centre of this stud is round, and the centre of the recoiling spring is hooked on to it; the other end of the recoiling spring is hooked on the barrel pulley. *Figs.* 1 and 8 show the impendent, made of the same metal as the case; it turns freely on a piece of steel *g*, *Fig.* 8; this steel arbor has a small knob on one side, *h*. shown at *Figs.* 1 and 8, to prevent the impendent from slipping off; on the other end it is split to receive the end of the chain which is pinned on; the pendent of the case is perforated, through which the chain passes. I shall next describe the manner it is to operate, and how it is to be put on the winding up arbor. When the barrel ratchet before mentioned is put on the square arbor, the recoiling spring is put on the barrel pulley, and placed over the barrel ratchet, so as to act on its click; the chain, which is no longer than to produce one revolution of the pulley, is put through the pendent, and hooked on to the pulley: the stud is then hooked on to the recoiling spring; by this stud the recoiling spring is set up one turn, more or less, and the stud is screwed on the plate. To wind up the watch, the impendent is drawn from the pendent as far as the chain will permit it; the recoiling spring will bring the impendent back again to the pendent; and this operation is repeated till the impendent remains on the pendent, and cannot be more drawn from it, which indicates that the main spring is wound up. When the works are to be wound up by a fusee arbor, the ratchet, which keeps the maintaining power, is on the fusee itself; the fusee arbor, squared, is on the same side of the plate as the going-barrel under the dial. The recoiling ratchet, *Fig.* 4, is put on the fusee arbor; its click and spring are on the barrel pulley, *Fig.* 6. Here it is to be observed, that when any works are to be wound up by a fusee, the fusee with the first wheel and its arbor returns back again, which is not the case with a going-barrel. *h* is the relieving click, which has a double action; first, it acts as the recoiling click, by its action in the ratchet; secondly, it acts as a reliever of the said click; it is planted on the under side of the barrel pulley, *Fig.* 6, with its spring, and must be made in the form shown in the drawing. That part which is near the edge of the barrel pulley has a small pin, which pin goes through an aperture of the barrel pulley into the groove where the chain lies. When the works are wound up, the impendent rests upon the pendent, and the chain lays round the pulley, which is the same as with the going-barrel. The pin of the relieving click, which goes into the groove of the barrel pulley, receives a pressure from the chain; it brings the click part out of the ratchet, and gives free action to the ratchet on the fusee arbor to return back again without any drag or incumbrance of the click. *l*, *Fig.* 1, is the finger touch: it is made of gold, or some metal which will not rust. By referring to the drawing, it will be seen that it is a kind of cup with a milled edge, and the minute-hand is fastened to it: when the hands are to be set, a slight pressure with the end of the fore-finger is required to turn the hands. In case it is desired to have a watch or clock wound up in one pull, the multiplying of the turns of the chain round the barrel pulley will have that effect.

The engraving on the next page exhibits a simple but very ingenious contrivance, termed by the inventor, (Mr. Knight, of Birmingham,) the "Patent Duty Register," which is designed to operate as a check upon public watchmen, and to ensure vigilance upon their part, by causing them to register the time at which they go their rounds, in a manner that will admit of no deception. Its uses, however, are not limited to this purpose, as it is equally serviceable as a check upon servants in general, and as a conviction of the correct information which it will infallibly afford to employers, it has a tendency to ensure punctuality on the part of those from whom it may be required. The train of wheel-work in Mr. Knight's machine being similar to those in ordinary clocks, the invention must be regarded as an addition or appendage, which is capable of being applied to clocks already made, as well as to those which are manufactured purposely to receive the new combination. The only essential variation consists in causing the circular dial-plate, which is usually fixed, to revolve, and the hand or index, which usually revolves, to be fixed. This stationary index

is placed at the top of the circle, and the hours, as they successively come under it, denote present time. This index forms part of a bended lever, the fulcrum of which is in the interior or back of the clock, and the other extremity of it is attached to a bell wire, with suitable cranks to carry the line of communication to the required place, where a handle is connected to it, for the individual who is upon duty or guard, to pull at stated times; this operation



raises the power end of the lever, and depresses the index, which makes a mark upon a temporary scale of hours fixed to the dial-plate, and indicates the precise time at which each mark was made. As the lever has only one centre of motion, it follows that the index, which forms a part of it, moves in the arc of a circle, and consequently would only strike upon a point; but to enable it to make a line, there is a spring joint where the lever is bent to a right angle, which allows the extremity of the index to move in a right line

over the plate. The clock face has two concentric circles of hours, the outer permament and of a full size, the inner temporary, and of small dimensions. The latter is an engraved print, the divisions upon which correspond radially with those on the outer circle, and it is intended that a fresh card should be put on the dial-plate every day; it is contrived so as to enable them to be put on with accuracy and expedition; the card taken off forming a register of the duty performed. *a* is the revolving metal dial-plate; *b* the revolving card; *c* an ornamental metal shield, to confine the card down to the plate, which is fixed to it by means of a thumb screw *d; l* is the marker, formed of a little sharp-edged wheel, revolving in a cleft at the extremity of the index, like a spur rowel, only without teeth; at *f* is the spring joint of the lever, before mentioned, forming the upper extremity of the lever. On depressing the lever. the end *f* takes the position of *e*, while *c* descends on the card dial and makes the mark. In our drawing, the time expressed is two o'clock; and if the handle be pulled, the index will descend from the position represented, and make the line drawn between the II, marked *s;* there are two other lines made upon the drawing, also marked *s*, which are intended merely as examples to show that such marks were made at the time expressed by the person on duty. The projection of the index in front of the dial is exhibited by the projection of its shadow thereon.

HORSE POWER. The force with which a horse acts is compounded of his weight and muscular strength. If, then, the weight of one horse exceed that of another to which it is inferior in muscular strength, the weaker and heavier horse will overcome a resistance which the stronger and lighter horse cannot, provided the excess of his weight in the smallest degree exceeds his deficiency in strength. When a horse draws in a mill or machine of any kind, care should be taken that the horse-walk, or circle in which he moves, be large enough in diameter, otherwise he can only exert a part of his strength; for, in a small circle, the tangent in which he draws deviates more from the circle in which he is obliged to go than in a larger circle. The diameter of the walk for full-sized horses ought not to be less than forty feet; but if such a space cannot be obtained, and the circle be reduced, it is advisable to procure horses of similarly reduced proportions; for it has been found that the same horse loses two-thirds of his effective strength in being removed from a walk of 40 feet in diameter to one of only 19 feet. In drawing a carriage, a horse works to the best advantage when the line of draught inclines a little upwards to his breast, making a small angle with the horizontal plane. With respect to the quantity of power a horse of average strength can thus exert, experimentalists have materially differed, owing probably to the limited extent of their trials, with horses of different degrees of strength, and under different circumstances; for much will depend upon the nature of the ground, the proper shoeing, the angle of draught, the fitting of the collar, &c. As a variation in these points will fatigue or cramp the full exertion of a horse, a great difference in the amount of a whole day's work must result; but if we take the average of the data thus furnished to us by the different authors and experimentalists on the subject, we shall find it to amount to 160 pounds' weight, raised at the velocity of 2½ miles per hour, the correctness of which has been most satisfactorily shown by some experiments on a very *extensive scale* by Mr. Bevan, that were recently communicated to the editors of the *Philosophical Magazine*. Mr. Bevan states, "In the period from 1803 to 1809 I had the opportunity of ascertaining correctly the mean force exerted by good horses in drawing a plough, having had the superintendance of the experiments on that head at the various ploughing matches, both at Woburn and Ashridge, under the patronage of the Duke of Bedford and the Earl of Bridgewater. I find among my memoranda the result of eight ploughing matches, at which there were seldom fewer than seven teams as competitors for the various prizes.

	lbs.
The first result is from the mean force of each horse in six teams of two horses each team, upon light sandy soil . . .	156
The second result is from seven teams of two horses each team, upon loamy ground, near Berkhempstead	154

	lbs.
The third result is from six teams, of four horses each team, with old Hertfordshire ploughs	127
The fourth result is from seven teams, of four horses each team, upon strong stony land (improved ploughs)	167
The fifth result is from seven teams, of four horses each team, upon strong stony land (old Hertfordshire ploughs) . . .	193
The sixth result is from seven teams, of two horses each team, upon light loam	177
The seventh result is from five teams, of two horses each team, upon light sand land	170
The eighth result is from seven teams, of two horses each team, upon sandy land	160

The mean force exerted by each horse, from 52 teams or 144 horses, is equal to 163 lbs. each horse; and although the speed was not particularly entered, it could not be less than at a rate of $2\frac{1}{2}$ miles per hour. As these experiments were fairly made, and by horses of the common breed used by farmers, and upon ploughs from various counties, the numbers may be considered as a pretty accurate measure of the force actually exerted by horses at the plough, and which they are enabled to do without injury for many weeks; but it should be remembered, that if these horses had been put out of their usual pace, the result would have been very different. The mean power of the draught horse, deduced from the above-mentioned formula, exceeds the calculated power from the highest formula of Mr. Lesslie, and, we may add, that of Mr. Tredgold. The latter gentleman has, however, furnished us with a most valuable table, showing the maximum quantity of labour that a horse of average strength is capable of performing, at *different velocities*, in drawing boats on *canals*, and carriages on *railways* and *turnpike roads.*

Velocity in miles per hour.	Duration of the day's work at the preceding velocity.	Force of traction in pounds.	Useful effect of one horse working one day, in tons, drawn one mile.		
			On a canal.	On a level, railway.	On a good level turnpike road
Miles.	Hours.	Lbs.	Tons.	Tons.	Tons.
$2\frac{1}{2}$	$11\frac{1}{2}$	$83\frac{1}{3}$	520	115	14
3	8	$83\frac{1}{3}$	243	92	12
$3\frac{1}{2}$	$5\frac{9}{10}$	$83\frac{1}{3}$	153	82	10
4	$4\frac{1}{2}$	$83\frac{1}{3}$	102	72	9
5	$2\frac{9}{10}$	$83\frac{1}{3}$	52	57	7.2
6	2	$83\frac{1}{3}$	30	48	6.0
7	$1\frac{1}{2}$	$83\frac{1}{3}$	19	41	5.1
8	$1\frac{1}{8}$	$83\frac{1}{3}$	12.8	36	4.5
9	$0\frac{9}{10}$	$83\frac{1}{3}$	9.0	32	4.0
10	$0\frac{3}{4}$	83	6.6	28 8	3.6

It will be seen by the foregoing, that the loss of effect is very considerable upon increasing the velocity of a horse beyond that of $2\frac{1}{2}$ miles per hour; this speed has, indeed, been considered by all writers on the subject, as the fittest for obtaining the greatest quantity of power from horses, as they can exert it without being overstrained, throughout a whole day's work. At the highest speed of 10 miles per hour, which is that of many of our stage-coach horses, it will be observed that they cannot keep up this pace for more than three quarters of an hour; that is, $7\frac{1}{2}$ miles per day is as much as they can perform without being soon exhausted. The amount of useful effect assigned by Mr. Tredgold for this day's work of only three quarters of an hour, is 3.6 tons drawn one mile, which is equivalent to nearly half a ton drawn $7\frac{1}{2}$ miles. Now the weight of an ordinary stage-coach and its load is about four times the last

mentioned quantity, or two tons; consequently we perceive the necessity of four horses being employed, as is customary, to do the work at that high velocity which one horse would easily perform at the velocity of $2\frac{1}{2}$ miles per hour. In stating the power of steam engines, it is usual to say the number of horses' power it exerts, each horse power being estimated as equivalent to raising 33,000 lbs. one foot high per minute. See the article STEAM.

HORSE-SHOES. Curved pieces of iron, made to fit accurately the horny hoofs of horses, to which they are nailed in a peculiar manner; the use of the shoes being to preserve the hoofs from the destructive effect that would take place by their collision and friction against the hard substances of which our common roads are formed. It is a common rule to make the shoes three times as thick at the toes as at the heels, so that by this means the frog (which is a central projection in the foot) may come down to the ground. The nails are all placed forward, four on each side, but not approaching too near the heels, and are countersunk in conical or wedge-shaped holes. For horses which go in shafts, or are used in hunting, it is usual to make shoes with only one heel, which should be outward. The horse's heel is rather lowered on that side, and the inner heel of the shoe somewhat thickened, so as to balance and bear equally. The best breadth for the shoe of a medium-sized horse is said to be one inch at the toe, and three quarters at the heel; the weight, about eighteen or twenty ounces. In order to fit the shoe without causing the horse to stand too much on his heels, the under part of the crust, or wall of the hoof, is pared away to receive the excess of thickness in front; for the bottom of the shoe, it is generally conceived, ought to be perfectly flat, without any stubbings or calkings in front. Paring away the heels is a most destructive practice, except in case of absolute excrescence in those parts; nor should the bars (or diagonal ridges) that extend from the heels to the frog, or central projection, ever be cut more than is absolutely necessary for the purpose of keeping them in a clean and healthy state. A good open heel is the indication of a powerful foot; hence the sides of shoes ought not to be much contracted; when the heels are tender, what is called a bar-shoe ought to be applied. On the frog the horse chiefly depends for a spring or resistance at the bottom of the foot: if this part does not touch the ground, the whole motion will be derived from the upper parts of the limb, and a very uneasy gait will inevitably follow: this points out the propriety of leaving it fully at liberty to come in contact with the ground. Mr. Colman, the distinguished professor of the Veterinary College, says, that "no animal, nor any part of the animal, can be preserved in health, where the natural functions are perverted; and he strongly urges the necessity of some great alterations being made in the practice of shoeing horses, so that a portion of the weight of the animal may be sustained by the frog, which, from its central projection in the foot, and the tough elastic nature of its substance, was evidently designed for that purpose. In a recent paper on the same subject, from the pen of Mr. Cherry, that gentleman entirely coincides with the author just quoted, and considers that *not only the frog, but the sole also*, (which is that horny portion of the foot between the frog and the exterior wall or crust of the hoof,) should be made to sustain its proportion of the superincumbent weight; and, he adds, that any treatment which deprives these parts of pressure, must, according to true physiological principles, induce disease. It is evident that a horse in a state of nature presses with the whole surface of his foot upon the ground, the rim of the hoof, by its angular projection, preventing slipping, and the frog serving as a cushion to prevent any ill effects from violent concussion. By the ordinary mode of shoeing, however, the whole weight of the horse is thrown upon this angular rim, or wall of the hoof, contrary to the designs of Providence, and the plainest dictates of common sense; for, being shod with a thick bar of iron on this part, the foot is thereby lifted up, forming a hollow cavity within the shoe, which, as Mr. Cherry says, "deprives the foot of that support which it would otherwise receive from the earth, and greatly deranges the mechanism of the whole foot." The same author proceeds to observe, that the feet of farm horses, though usually in that condition termed a state of neglect, will, upon examination, be found generally "moist, cool, and healthy;

while a foot kept clean, is dry, brittle, and full of cracks;" which is evidently owing to the shoes of the former being usually clogged with earth, by which the whole surface of the foot is made to sustain the pressure, instead of the mere rim; the earth likewise contributes to the healthful condition of the feet by a supply of moisture for absorption. "Perhaps," Mr. Cherry continues, "it may be possible to prepare some compressible and adhesive substance to fill up the cavity after the shoe is on, which shall give support to the whole foot, yet without impeding the full action of its elastic properties."

The late Mr. Robert Dickenson entertaining the same views of the subject as the above-mentioned eminent authorities, took out a patent for some improvements in horse-shoes, of which the following is a description. In the annexed engraving, *Fig.* 1 exhibits a plan; and *Fig.* 2 a side view of the improved shoe as fitted on to the foot. *Fig.* 3 represents the ordinary English

Fig. 1.

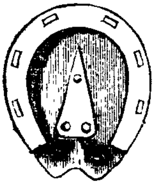


Fig. 2.

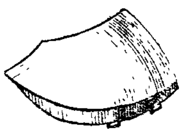
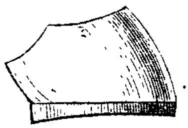


Fig. 3.



mode of shoeing, which has been here introduced merely by way of contrast. By Mr. Dickenson's plan, a piece of stout leather is cut to cover the whole under surface of the hoof; and on this is rivetted a plate of iron of a shape and magnitude to cover the frog, which it is designed to protect against injury in travelling upon hard stony roads; under the leather covering is stuffed into the hollow of the hoof a quantity of sponge, and the shoe being nailed on through the leather, the whole is thus simply and permanently secured until the iron shoe is worn out, the leather lasting out several iron shoes, owing to its compressible elastic nature. The absorbent nature of the sponge keeps the foot always moist, and the whole surface of it is brought to sustain the pressure. It will be observed that the iron rim of Mr. Dickenson's shoe is curved after the French manner, as shown in *Fig.* 2. From the rapid action of a horse's foot it is not easy to discover the precise kind of motion which he makes in stepping out and relieving his foot for the next step; but it is ascertained to be a rolling from heel to toe. Now the flat shoe represented in *Fig.* 3, which is the common English form, evidently presents an obstruction to this particular action; frequent stumbling from an unnatural effort to overcome the difficulty, and a straining of the muscles and tendons, to which nature has assigned due limits, seem to be the unavoidable consequences. On the contrary, the French shoe is so curved as to conform to the natural figure of the hoof, and consequently presents no impediment to the natural action of the foot; to this circumstance may therefore probably be attributed the well-known superior surefootedness of French horses. The impropriety of a perfectly flat shoe is manifested by the toe part being generally worn down as thin as a sixpence, while the sides are frequently half an inch thick.

With the view of obviating the presumed necessity of fastening the iron shoes to horses by nailing them to the hoofs, Mr. William Percival, of Knightsbridge, took out a patent in 1828 for a mode of securing them to horses' feet by means of straps or sandals. In the engraving on the following page, *Fig.* 1 represents a plan of the shoe, which is of the kind called the frog-bar shoe; in the front is a tongue *a*, turning upon a hinge, and having two slits in it to receive the band or strap, and keep it in its place; at the extremities of the frog-bar are two double loops or rings, *b b*, turning upon hinges or holes in the ends of the bar. *Fig.* 2 shows the shoe attached to the foot of a horse, the strap *c*, of elastic web, is passed through the lowermost of the two rings; through the lowermost slit in the tongue; through the lowermost ring on the opposite side; then through the uppermost slit in the tongue; and afterwards

through the buckle on the other end of the strap, and drawn tight. The strap *d* is passed through the uppermost of the two rings on one side, and over a pad *e*,

Fig. 1.

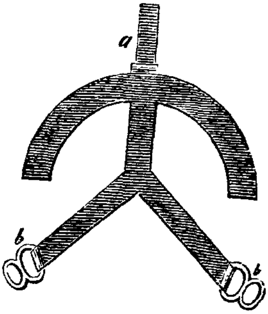
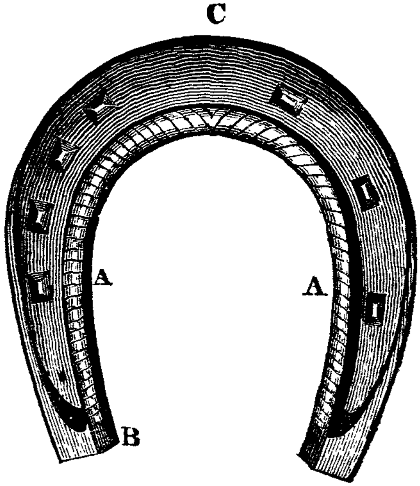


Fig. 2.

placed under the heel of the animal, then through the uppermost rings on the opposite side, over a pad *f*, and secured by a buckle on the other end of the strap.

Mr. Benjamin Rotch, the barrister, has distinguished himself by his attention to this subject, which so intimately concerns not only the welfare, but the utility of the most interesting and valuable animal in the creation. In 1810 he had a patent for a flexible elastic horse-shoe; and in 1830 a second patent, entitled "improved guards or protectors for horses' legs and feet under certain circumstances;" and as this patent may be regarded as an improvement upon the former, we shall notice the latest only. These "improved guards" are to be made of caoutchouc, or Indian rubber; when one is to be applied to a horse's foot, the neck is to be cut from a caoutchouc bottle, which is then to be softened by immersion in hot water, and drawn over a block made of the shape and size of the foot for which it is intended. On this block it is permitted to cool, when it will retain its shape; and by its elasticity it will adhere to the horse's foot when drawn on to it. On the exterior of this shoe is to be applied a sole of sheet-iron, made of sufficient size to allow of its edges being cut and turned up round the hoof, to keep it on the foot; but it is also fastened to the Indian rubber by means of rivets with very broad and thin heads; and to the sheet-iron sole is to be fastened, if required, horse-shoes of the usual forms. In the preparation of the guards for the legs of horses, both the top and the bottom of an Indian rubber bottle are to be cut off, and after being soaked, softened, stretched on a block, formed, and cooled, is to be applied to such of the legs or knees of the animal as require protection.



For the purpose of ensuring a perfect fit to a horse's foot at a small expense, Mr. Dudley, of King-street, Soho, took out a patent in 1823 for a horse-shoe of *cast*-iron, an under side, or ground view of which is represented in the annexed cut. After being cast to the precise model of the foot taken from a plaster cast, it undergoes that process of annealing (now so well understood and practised) by which it is rendered so soft and malleable as not to be liable to break by concussion in travelling over the roughest pavement. At A A is

a raised border, or cord, the use of which is to strengthen the inner vein or web, also to prevent pieces of flint or gravel, &c. from being forced on the sole of the foot, which frequently happens with the common shoe, as that affords no such protection. This form is also considered by the patentee to give great security to the tread of the horse, either over pavement, road, or field. At the ends B of the shoe, concavities are formed, which become stops, equal in effect to the rough shoeing, or turning up at the heel, without altering the even bearing of the horse's feet upon the ground, so essential to his true motions, and the security of both horse and rider. If proper attention be paid to the manufacture of these shoes, especially the annealing process, they would prove of great utility, as they can be quickly made of any size, figure, or pattern, exactly suited to the feet of any particular horse, and supplied in any quantity, all precisely alike.

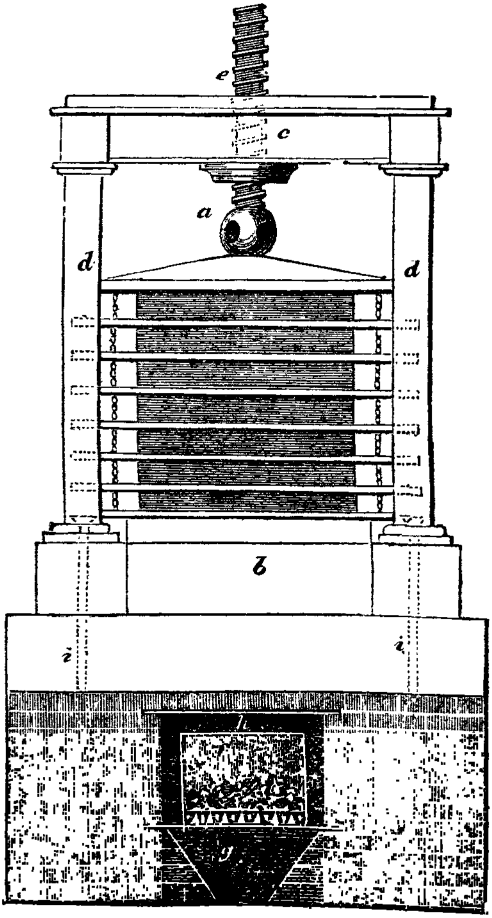
HOSE. A term given to a flexible tube attached to hydraulic engines, for conveying water or other fluid to any required point. Fire-engine hose was originally made of leather sewed up, which being very liable to get out of order, many attempts have been made to discover some cheaper and more durable material. Flax, or hempen hose, woven without a seam, have long been employed on the continent; and the Society of Arts, in London, have for years past been in the habit of offering a reward for its production in this country. According to Beckmann, however, a manufactory for this article existed in the neighbourhood of Bethnal-green, towards the end of the eighteenth century, but the speculation did not succeed. One of the London Insurance Offices a few years since imported a length of the best hempen hose from the continent, but it did not answer, being found not near so convenient in use, nor so durable as leather. Mr. Hancock has manufactured some hose of canvas, with layers of caoutchouc between them, which has been found useful in many cases where leather would have been ineligible. Leather hose was formerly made by sewing with strong twine, and subsequently with copper wire; neither of these methods, however, was found sufficient to keep the hose constantly water-tight, and all the best hose now made is not sewn at all, but rivetted. The fire-engine establishments of London and Edinburgh make their own hose; the method adopted by them is as follows: the leather, levelled to a proper thickness, and in lengths of about four feet, is gauged to the breadth required; holes are punched, four at a time, all down the sides, by means of a small press. The ends of each piece of leather are cut crosswise, at an angle of about 37°; the different pieces of leather necessary to form a *length* of hose (forty feet) are then rivetted together at the ends. The length of leather thus formed is then placed on a bench, and a long flat iron bar laid upon it; the rivets are next put into the holes on one side of the leather, and the holes on the other side brought over them; washers are then placed on the rivets, and struck down with a hollow punch. The points of the rivets are then hammered down over the washers; this done, the bar of iron is shifted along, and the operation continued until the whole length is completed. A piece of rivetted hose made in this manner has been found capable of resisting a column of water nearly 500 feet high. The following composition has been found most efficacious for the preservation of leather hose, viz. one gallon of neat's-foot oil, two pounds of tallow, and a quarter of a pound of bees'-wax, melted together, and applied warm, the hose being in a moist state.

HOT-BEDS, in Gardening, are beds made with fresh horse-dung, or tanner's bark, and covered with glasses to defend them from inclement weather.

HOT-HOUSE. A garden erection, similar to a green-house, employed either for forcing plants, or for the training of exotics, provided with a stove or flue for the diffusion of artificial heat, and the means of duly regulating it.

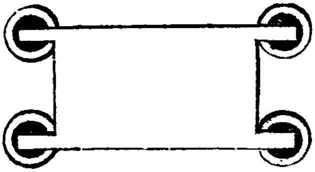
HOT-PRESSING is, strictly speaking, the art of applying heat in conjunction with mechanical pressure; but it is generally understood to mean the employment of that process to paper, linen, and similar fabrics, by which they acquire a smooth and glossy surface; and the mode of operating is as follows. A number of stout cast-iron plates are heated in an oven constructed for the purpose; when they have acquired the proper temperature, they are taken out and put

into a screw-press, in alternate layers, with the goods to be pressed, in the manner shown in the subjoined engraving; and when paper is the material to be hot-pressed, in addition to the heated iron plates, a highly-glazed pasteboard is put alternately between every sheet of paper; the hard polished surfaces of the pasteboards, in consequence, produce upon the soft and spongy sheets of paper that smooth and elegant appearance by which hot-pressed paper is distinguished. The great inconvenience and labour attending the drawing of the heavy hot iron plates from the oven, then carrying them to, and lifting them into the proper situations in the press, struck the editor of this work as susceptible of amendment. With this view of the subject he devised a press from which the plates never required removal, and wherein they are constantly kept at the required temperature by hot air from a small furnace beneath. By this arrangement, fuel, time, labour, and space, may be saved. The press itself, as shown in the subjoined elevation, does not materially differ from those in



general use. The bed *b*, and the head-piece *c*, must be of the most solid and tenacious materials; these parts are braced and held together by four stout cast-iron hollow columns or cylinders *d d*, having a longitudinal slot mortice throughout their length for the reception of the corner pieces of the plates, as shown by the

annexed diagram, which exhibits a plan of a plate, with its four corner pieces inserted in the slots of the cylindrical columns, the dark central parts of each being the space where the hot air acts upon the corners of the plates; the heat from which, by the conducting power of the metal, is quickly communicated throughout. A series of these plates is shown in the elevation,



attached to each other by means of short pieces of chain, which allow the plates to be pressed nearly close together, or the drawing of them further apart by the action of the screw *e*. The ends or corner pieces of the plates are shown by dotted lines, as inserted in the hollow columns. The furnace or fire-place is placed underneath at *f*; at *g* is the ash-pit, and at *h* is the hot-air chamber. The bars of the furnace are made hollow, which, being heated by the burning fuel, the cold air rushes through them, abstracting caloric in its passage, and is received at the back into the hot-air chamber, which lines the sides, top, and part of the back of the fire. The air in this chamber derives a great increase of heat by radiation through the iron partition which separates it from the fire. The hot-air chamber is of course kept closed, the front plate being merely removed in the drawing to show its form; a sliding plate should be made to fit the front ends of the hollow bars, by which the quantity of air admitted may be lessened or augmented; and by a due attention to the management of the fire, the heat may easily be regulated with sufficient exactness for the nature of the operation. The hot-air is conducted from the chamber *h*, by means of four iron pipes, and to each of the cylindrical pillars; two of these are shown by the dotted lines *i i*. As the hot-air issues from these pipes it ascends the columns, impinging in its progress upon the ends of the plates, and heating them to the degree required for hot-pressing. For fire-proof houses, see the article FIRE.

HOUSE. A building constructed for the purpose of habitation. The recent improvements made in the construction of the constituent parts of houses, such as windows, shutters, roofs, chimneys, &c. we have given under their respective heads; and as it would be trespassing far beyond the assigned limits of this work to introduce into it a regular treatise on the subject of house-building, it is with satisfaction that we can recommend to the attention of the inquiring reader, *Nicholson's Practical Builder*, in which the modern practice of this most important art is clearly developed in all its details.

HOWITZER. A kind of artillery between a cannon and a mortar; being longer than a mortar and shorter than a cannon, and from that circumstance adapted to throw either shot or shells; it is usually mounted as a cannon upon a travelling carriage.

HULK. A large vessel moored and fitted up for the purpose of taking out or putting in the masts of other ships, and for various other purposes that may be required in nautical affairs. They are sometimes employed to contain stores, and sometimes for the secure detention of prisoners.

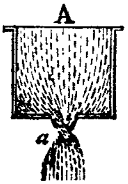
HUNGARY WATER is made by distilling, in a water bath, two pounds of fresh-gathered flowers of rosemary, with two quarts of the rectified spirit of wine.

HURDLES. A light fence of open rails, made in convenient detached pieces, for fixing separately in the ground by stakes or prongs; the hurdles being afterwards tied together, end to end, constitute a continued fence. Until recently they were almost wholly made of split oak or other tough wood; but now, from the low price of iron and the facilities of manufacturing, iron hurdles are extensively used.

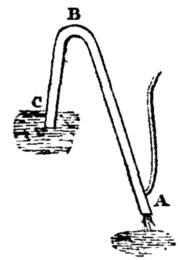
HYACINTH. A sub-species of pyramidal zircon. Colours red, brown, green, and grey, and more rarely yellow. The darker varieties are deprived of their colour by heat, a fact of which artists avail themselves to make zircon resemble diamond. It is esteemed by lapidaries as one of the gems.

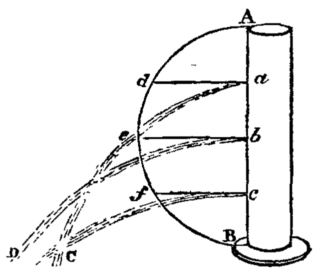
HYDRATES. Compounds, in definite proportions, of metallic oxides with water.

HYDRAULICS is the term applied to that collection of facts which describe the phenomena of fluids in motion. In treating of hydrostatics, we have shown that fluids press in all directions, and that the pressure is as the depth: hence if a small hole be made in the bottom or side of a vessel, the velocity with which the water will issue will depend on the pressure above it, that is on the depth of the hole. If a vessel be kept quite full of water, so that the height may remain fixed, and holes be made at various depths beneath the surface, it will be found that the velocity of the issuing fluid will be as the square root of the depth of the hole. Hence to produce the velocities 1, 2, 3, 4, the corresponding depths must be 1, 4, 9, 16, which are the squares of the velocities. To produce a double velocity we see a fourfold pressure is required. To explain this, we must bear in mind that when the velocity is doubled, a double quantity of fluid must issue, and as this issues with a double velocity, the power requisite to produce this effect must be four times greater. In like manner three times the quantity of fluid issuing with three times the velocity, will require a power nine times greater, and so on. This law, it will be seen, is coincident with that of bodies falling in free space by the power of gravity. To produce a double velocity, a fourfold height is required; to produce a threefold velocity, a ninefold height is required. Thus it appears if a particle of water were to fall unresisted from the surface of the fluid to the orifice, it would acquire the same velocity as the issuing water actually exhibits. If a small tube were attached to the orifice and turned upwards, the water would ascend to a height equal to its source, were it not for the resistance of the air, and the friction against the sides of the tube. The absolute velocity of the fluid cannot be ascertained by calculation alone, and must therefore depend partly upon experiment. In the annexed cut it will be seen that the particles of water, on account of the equality of pressure on all sides, will so far interfere with each other's motion, that the stream will be contracted a little below the orifice. This contracted part was called by Sir I. Newton, who first observed it, the *vena contracta*, or contracted vein; and its magnitude compared with that of the orifice, was found to be as one to the square root of two nearly, or as 1000 to 1414. Now the velocity found by the rule we have before stated is the velocity at the *vena contracta*. But as the velocity of fluids in a channel varying in diameter is inversely as its sectional area, the velocity at the orifice is less than at the *vena contracta* in the proportion of 1 to 2, or as before stated, as 1000 to 1414. Hence it follows, that the velocity at the orifice is that which a body would acquire in falling through half the *altitude* of the fluid above the orifice. From this theorem we may easily calculate the quantity of water that would escape through a given orifice in any time. Let a cistern or other vessel be six feet high, and kept full of water, and it be required to ascertain what quantity of water would run out through a hole a quarter of an inch area, near the bottom, in ten minutes. By the laws of mechanics we find that the velocity acquired by a body falling through half the height, viz. three feet, is fourteen feet in a second; if, then, we multiply the area of the orifice, namely a quarter of an inch by 14, and then by 600, the number of seconds in ten minutes, we shall obtain 2100 cubic inches, or seven gallons and a half as the issuing quantity. The quantity of water that issues through a hole in the bottom of a vessel may be varied by inserting small tubes in the holes. Thus it was found by Venturi that when a small tube was applied whose length was equal to twice the diameter of the hole, it discharged eighty-two quarts of water in one hundred seconds, while the hole without the pipe discharged but sixty-two quarts in the same time. If the pipe, instead of being level at its top with the bottom of the vessel, projects some distance within it, it diminishes the discharge to less than would occur with the simple hole. In the preceding view of the velocity of discharge we have considered the surface of the water as maintaining the same level; but in ascertaining the time in which a vessel would empty itself through a given hole, it must be evident that attention must be given to the varying depth of the fluid. If the fluid flow with a velocity of sixteen feet

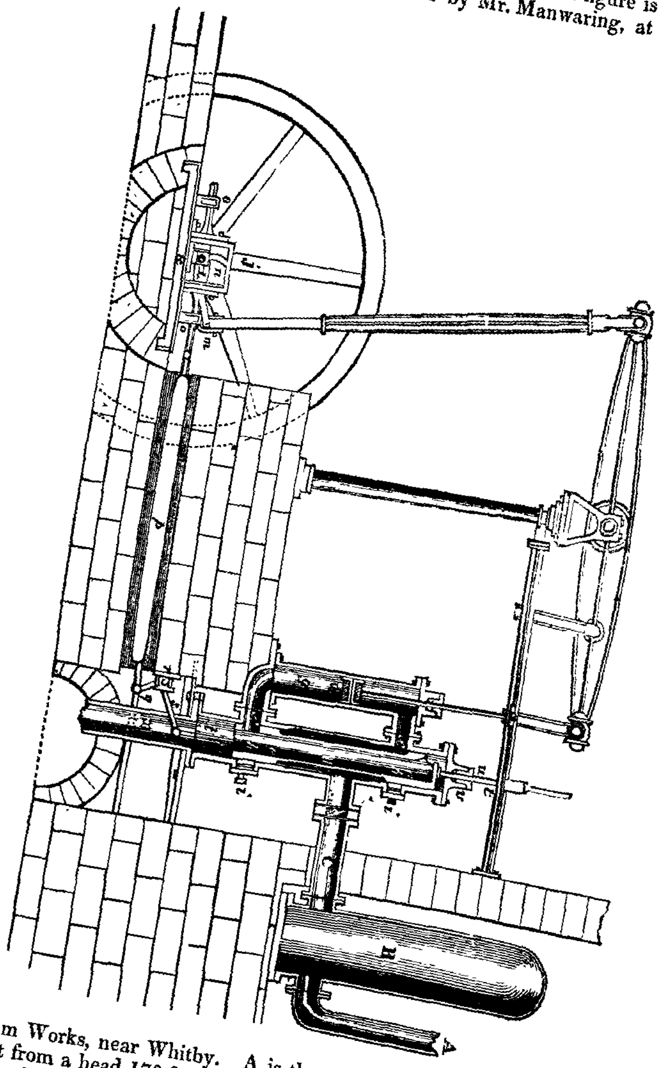


per second, when the vessel is full, it will flow with a velocity of eight only when the vessel has discharged three-fourths of its contents, that is, when the height is reduced to a quarter of its original altitude. If it be considered that the pressure is continually diminishing with the flow of water, it will easily be conceived that the quantity of water that will flow out will be only one half of that which would be discharged if the vessel were kept full. In this case the surface would sink with a gradually retarded motion; and if the sides of the vessel were marked with a series of numbers representing the hours of the day, it would form the clepsydra, or water-clock of the ancients, the surface of the water being the index. The same law applies to the conveyance of water through valleys in pipes, as we have shown to exist in the issue of water from holes in the bottoms of vessels. If it were required to convey water across a valley of considerable depth, the pipe employed must have great strength to withstand the pressure arising from the height of its source. If a small hole were made in the pipe the height to which the water would ascend, would indicate the great pressure existing. In this way various fountains may be constructed. In conveying water from a higher to a lower level, when it is inconvenient to form a channel, the syphon may be employed. This consists of a bent tube, A, B, C, having a shorter and a longer leg. The shorter leg is placed in the water to be removed, and the air being then drawn out through a tube communicating with the longer leg, or by means of a stop-cock, the water will rise in the shorter leg by the pressure of the external air, and going over the bend of the tube, will run in a continuous stream as long as the level of the water at A is lower than that at C. In the flowing of water through holes in the sides of vessels, the same proportions obtain as in the discharge through holes in the bottom. If A B represent a vessel kept full of water, and holes be made in the sides at *a b c*, the water will be found to spout to different distances, and yield different quantities according to the depth of the orifice. Thus the quantities of water that would flow from *a* and *c* would be as 1 to 2, because their depth are as 1 to 4; and from any other hole the quantity would still be as the square root of its depth. If a semicircle be imagined to stand with its diameter on one side of the vessel, and lines be drawn perpendicular to the diameter, as *a d*, *b e*, and *c f*, these lines will show the proportionate distances to which the fluid will spout. The *vena contracta*, in this case, being very near the vessel, the velocity of projection at this point must be considered as the true velocity; and this is equal to that acquired by a body falling through the whole height of the fluid above the hole. The curve *c* C described by the water, is a parabola, whose vertex is at *c*: and by a property of the parabola, B C, the distance to which the fluid spouts from B is equal to twice the square root of (B *c* multiplied by *c* A) which is equal to twice *c f*. In a vacuum, therefore, double the lines *a d*, *e b*, *e f*, represent the distances to which the fluid would spout. If the water, instead of flowing through a very small hole, had to flow through a long slit, the velocity would differ at the top and bottom, and in this case, the point which may be taken as that of the mean velocity, is two-thirds of that at the lowest point. In the action of liquids, as in solids, a considerable quantity of power is constantly consumed in friction; hence the velocity of water through pipes or jets is considerably diminished, as is also the motion of rivers, a circumstance which is essentially beneficial to navigation; for otherwise, the velocity of the water, continually increasing in its fall, would become so great as to be unmanageable. For further information in this science, consult the articles, PUMPS, WATER-WHEELS, and the various hydraulic machines.





HYDRAULIC ENGINES, are all kinds of machines which either receive motion from the weight or impulse of water, or are employed in raising it; but the term is sometimes used to denote a machine which in its general construction resembles a steam engine, but the piston of which is impelled by the pressure of a column or head of water. The annexed figure is a representation of a statical hydraulic engine erected by Mr. Manwaring, at Messrs. Cook &

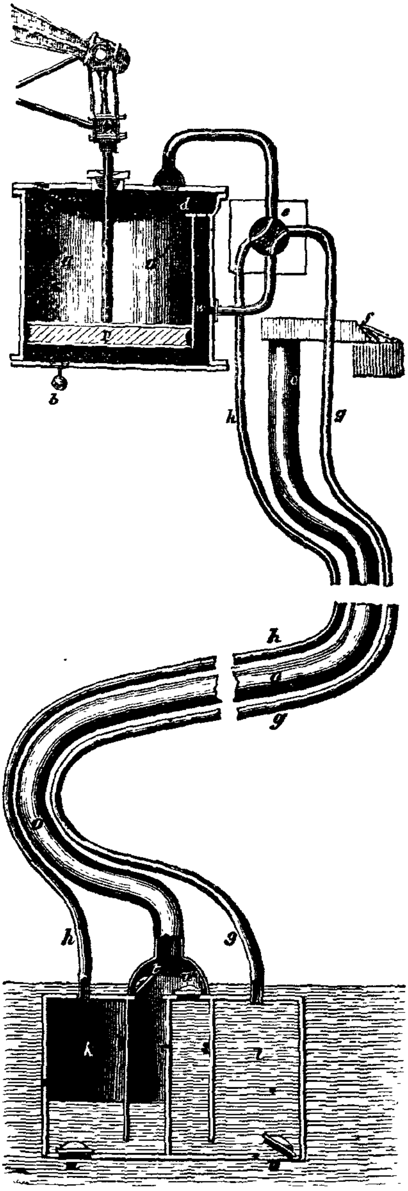


Co.'s Alum Works, near Whitby. A is the pipe by which the supply of water is brought from a head 170 feet above the engine; B is a vessel containing air, the continual elastic pressure of which prevents the blow that would otherwise be occasioned by the descent of the water; *c* is a throttle valve; *d d* is a hollow open cylinder, working within an exterior one, and closely applied to that cylinder, at the parts *e e e e*, but elsewhere leaving a vacant space between the two cylinders for the reception of the water; *h h* are packings, in order to

prevent the escape of the water between the two cylinders; and *i i* are adjusting screws, to tighten the packing in proportion as it is worn away; *f f* are two passages that lead into the upper and lower ends of the pipe *g*, in which the piston *w* works. When the cylinder *d d* is in the position represented in the cut, the communication is open by means of the upper pipe *f*, for the water to flow into the pipe *g* above the piston *w*; at the same time the passage is open for the water in the cylinder *g*, below the piston, to flow out through the lower pipe *f* and through the lower part of the open cylinder *d*, into the pipe *x*, which is somewhat more than 30 feet long, and terminates in a cistern of water. There is therefore, above the piston *w*, a hydrostatic pressure equal to 170 feet of water, and below it a partial vacuum; the piston consequently descends to the bottom of the pipe *g*. By the time that it has arrived in this position the cylinder *d* will also have descended so far as to have opened the communication between the entering water and the lower pipe *f*, and to have shut off its communication with the upper pipe *f*; the hydrostatic pressure is therefore transferred to the under part of the piston, which consequently rises, while the water above the piston pours into the top of the cylinder *d*, and escapes through the pipe *x*. The alternate motion of the slide or cylinder *d* is thus effected. The rod of the piston *p p* is attached at its top to one end of the beam; at the other end of the beam is a rod, terminating below in the crank *m*; the oscillating motion of this crank is transferred, by means of the connecting bar *l*, to the axis *k*, on which is placed the curved tooth or cam *n*; the latter is enclosed within the rectangular frame (or cam box) *j*, and, being movable in a horizontal position, is consequently made to perform a backward and forward motion, by the cam passing first on one and then on the other side of the box. To the outside of the box are fixed two guide bars, supported on thin bearings *o o*, the connecting rod *p* at one end to the guide bar, and at the other end to the arm *q* of a bent lever, having for its fulcrum the pivot *r*; the other end of the lever is forked, and embraces the pipe *x*; one of these forks *s* is connected with the lower end of the upright rod *t*, and the other fork is connected with a similar rod. These rods are fastened at top to the two ends of a cross bar, to the middle of which is fixed the rod *u*, which works in the stuffing box *v*, and gives motion to the slide *d*. The slide remains stationary nearly half a stroke of the piston, in order to allow the water to act with its full force; and this is effected by its being necessary for the cam, after it has moved the box in one direction, to perform about a quarter of a revolution before it can act on the opposite side of the box. The reason for making the passages *f f* as large as represented, is to diminish as much as possible the friction of the water, which otherwise would retard the motion of the piston. Engines upon the principle of the above have been long known, and some were erected in Cornwall more than sixty years ago. Some of the earlier attempts to construct hydraulic engines upon the principle of the steam engine failed, because water, not being elastic, could not be made to carry the piston onwards a little, so as to close one set of valves, and open the other. In an engine erected by Mr. Trevethick, about thirty years ago, a tumbler connected with the valve gear performs the office instead of the expansive force of the steam at the end of the stroke. This is now, however, much better effected by the introduction of an air vessel similar to that shown in Mr. Manwaring's engine, which has besides, the effect of preventing a concussion at the end of each stroke.

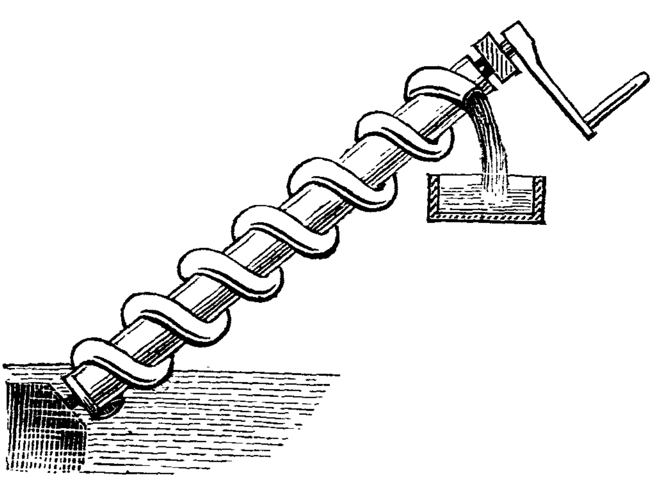
Mr. Seidler has taken out a patent for an engine, which he calls a hydraulic engine, but which we think should rather be styled a pneumatic engine, as raising water is merely one of the objects to which he proposes to apply the principle, which is that of employing compressed air as a medium for transmitting the power of any prime mover to machinery at a distance, or in situations where the ordinary modes of connexion would be inconvenient or impracticable. The principle itself is very old, having been employed by Papin as noticed under the word Air. The engraving on the next page represents the application of the principle to the purpose of raising water from any depth, and through straight or circuitous passages. *a a* represents a cylinder, in which a piston, *p*, works by means of a steam engine or other power. *h g* are copper pipes, forming a

communication between the cylinder *a a* and the cast iron tank or vessel *k l; o o* is a large delivery pipe, of copper or other material, through which the water is conveyed from the tank, and discharged; at *r* is an air-tight partition, dividing the tank into two parts, *k* and *l;* and *s s* are two air-tight partitions, proceeding from the top nearly to the bottom of the tank; *e* is a two-way cock, for effecting an alternate communication between *a* and *k*, and between *a* and *l*. The other parts of the machine will be explained in the following description of its action. Suppose the piston *p* to be raised from its present position in the cylinder, the air above it will be conveyed through the valve *c*, and the pipe *h* into the vessel *k*, and force the water contained therein through the valve *t*, up the pipe *o o*, while air will be supplied to the cylinder below the piston through the valve *b*. When the piston descends, the air will pass from the lower to the upper side of it by the valve *d;* this operation is to be continued till all the water is forced out of *k*, when the two-way cock *e* must be turned to change the communication through the valve *c* to the pipes *g*, and the part of the tank *l* at the same time; the air which was forced into *k* will be permitted to re-enter the cylinder through the pipe *w*, as shown by the dotted lines in the cock *e*, so that no air will be required to enter at the valve *b* except at the commencement of the operation, or when any of the air is discharged with the water, or otherwise dissipated. When the air is liberated from the receptacle *k* of the tank, it will be again filled with water through the valve *m*, the valve *i* being shut by the pressure of the water in the pipe *o o*. During this time, the water in *l* will be forced through the valve *u;* in the same manner from *k*, through the valve *i*. The cock *e* to be turned by the hand or by the machinery, after such a number of strokes of the piston in the cylinder as is sufficient to displace the water in one division of the tank. For machines for raising water, see Pumps and Water Works.



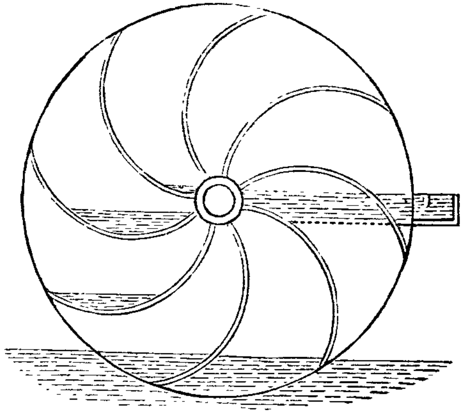
HYDRAULIC MACHINES. Under this head we propose to notice various machines which are at times employed in lieu of pumps for raising water, or which have been proposed for that purpose. The most simple, as

well, perhaps, as the most ancient (next to the bucket and windlass), is the Cochlion Water Screw of Archimedes. It consists of a cylinder of wood, of about a foot in diameter, and of any length at pleasure, and on this a leaden pipe of any bore is wound from the bottom to the top. When the bottom of the cylinder revolves in the water (by means of a common winch handle at top, and of a pintle in the centre of its base, which rests in a bore or step for that purpose below,) the reclined portion, as shown in the following figure, occasions the water to enter the mouth of the pipe, and as by its gravity it naturally occupies the lowest part of the pipe, whilst by the revolution of the cylinder the orifice of the pipe is gradually elevated, and a different portion of the pipe occupies the lowest position, the water advances progressively along the pipe, always occupying the lowest portion of the bends or turns of the pipe, until it at length reaches

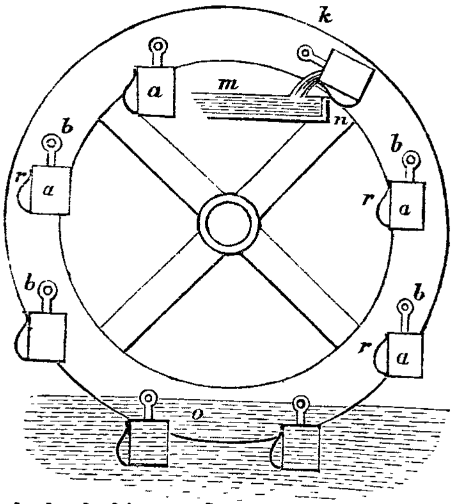


the top of the cylinder, and is discharged into a vessel. This, however, raises but a small quantity, although the height may be indefinite; therefore, when this machine is used, it will be found eligible to cover the whole surface of the cylinder with a number of pipes laid close together, or, what is a better method, and is that which is usually adopted, is to wind a number of spiral feathers round the cylinder, standing out from it at right angles like the square threads of a screw, and covering these feathers with an exterior case closely fitting in every part. These machines were formerly in great repute; but, owing to their liability to become choked with weeds and mud, they are not often employed at present.

The figure on page 720 represents what is called the horn-drum; it is formed of a number of segments passing from the circumference of a large flat cylinder to its centre. This affords an easy mode of raising water. The mouths or scoops by turns dip into the water, and as they rise cause it to pass up the horn or segment, until it is discharged into a trough placed under the end of the axis, which is hollow, and is formed into a number of separate compartments, each communicating with one of the horns or segments. One disadvantage of this machine is that it raises water no higher than the axle, and is therefore only applicable in situations where the water is required to be raised to an inconsiderable height. This circumstance renders it necessary to construct it of double the diameter of wheels that discharge their water at their tops. This machine, however, might be altered to do so likewise, by confining the scoops to near the periphery of the wheel, and discharging them by means of lateral valves, to be opened by coming against a contrivance fixed at the top of the



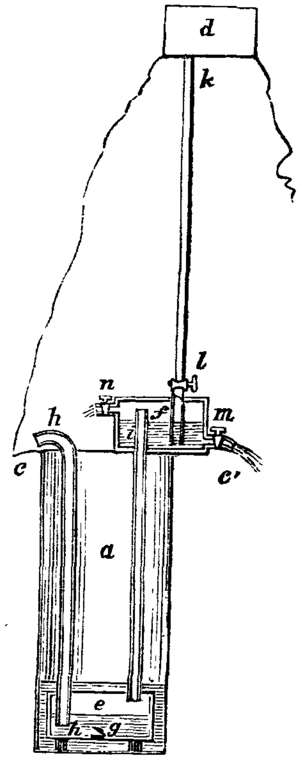
wheel for that purpose. The Persian wheel, represented in the following engraving, is free from the defect of the last described. In this machine a number of rectangular buckets *a a a a* are hung upon strong pins *b b b b*, fixed in the side of the rim, the diameter of which must somewhat exceed the height to which the water is required to be raised. As the wheel turns, the buckets on the right hand descend into the water, where they are filled, and return up full on the left hand, until they arrive at the top at *k*, where they strike against the end *n* of the fixed trough *m* by which they are overset, and thus discharge the water into the trough, from which it may be conducted by pipes to wherever it is required; and as each bucket gets over the trough, it falls again into a perpendicular position, and so goes down empty until it comes to the water at *o*, where it is filled as before. On each bucket is a spring *r* which, as it passes over the edge of the trough, elevates the end of the



bucket above the level of its mouth so as to discharge the whole of the water into the trough. These springs are likewise useful in preventing the concussion of the buckets against the trough. This machine, as well as the horn-drum, is frequently driven by means of floats attached to the opposite side of the rim.

The Hungarian machine, so called from its having been employed in draining a mine in Chemnitz, in Hungary, produces its action by the condensation

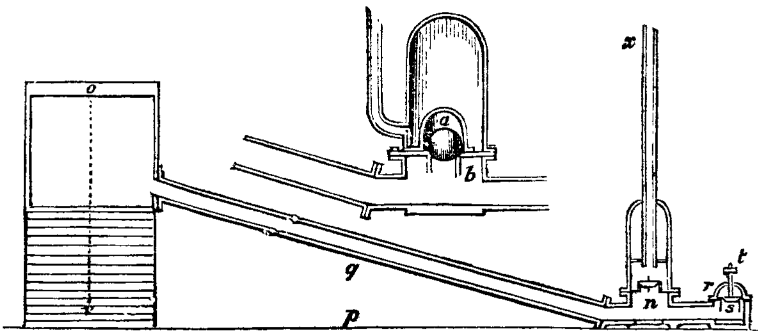
of a confined portion of air, produced by the descent of a high column of water contained in a pipe, and therefore acts with a force proportionate to the weight of such column. Its general form is shown in the annexed cut, by which it will appear that it is an exceedingly simple and useful machine, admitting of many modifications and applications; but it can be used only in hilly countries, or situations where the source of water by which it is to be worked is as much above the top of the well as the water to be raised is underneath it. In this figure *a* is supposed to be a well, or the shaft of a mine, from the bottom of which it is necessary to raise the water standing at the level *b b*. *c c* is the surface of the ground at the top of the well or shaft, at which the discharged water must have an opportunity of escaping, either by running to waste, or being converted to some useful purpose; and *d* is the spring or other elevated source from whence the supply of water for working the machine may be obtained. The machine itself consists of three cisterns, chests, or reservoirs, two of which at *e* and *f* must be made very strong, and perfectly air-tight, while the third at *d* may be weaker, and open at the top, as it is merely for collecting and retaining the spring, rain, or other water for working the machine. The lowest close chest or reservoir *e* must be sunk below the surface *b b* of the water in the shaft or well *a*, but must not come into contact with its bottom, otherwise the water would be prevented entering the chest by the valve *g*, which opens inwards for its admission. An open pipe *h h* passes from very near the bottom of this chest, through its top, in an air-tight manner, and proceeds upwards in the shaft as far as the surface of the ground, where it bends over to deliver its water, as at *h c*. Another open pipe *i i*, which may be of rather smaller dimensions than the last, proceeds from the top of the lower chest *e* to very near the top of the second chest *f*; and a third pipe, *k l*, of the same capacity as the first, proceeds from very near the bottom of the second close chest, up to the bottom of the high reservoir *d*, but has a cock or valve at *l*, by which it can occasionally be shut or opened. A cock or valve, of large dimensions, is also fixed at *m*, by which the second chest *f* can be emptied of its water, and a smaller cock is fixed higher up, as at *n*, for discharging its air. To set the machine in action nothing more is necessary than to shut the cocks *l* and *m*, and open the cock *n*, from which the air previously contained in the lower chest will escape, and its place will be filled up by the water *b b*, which will pass through the valve *g*, until the chest *e* is completely filled. That done, the air cock *n* is to be shut, and the water cock *l* opened, when a column of water, equal to the full height and pressure of the cistern *d*, will rush down the pipe *k l*, and by filling the chest, will expel its air, which has no other opportunity of escaping but by the open pipe *i i*, down which it will pass, and produce a pressure on the surface of the water in the lower chest equal to the entire height of the column *k l*; and the air thus thrown into the chest *e*, being in a condensed state, will form the



water previously in that chest up the pipe *h h*, from whence it will be discharged at *c*. The lower chest *e* will now be filled with air, while the upper chest *f* will be occupied by water: therefore the cock *l* must be shut, and that at *m* opened, when the whole of the water from *f* will be discharged at *c*, and will give the air in *e* an opportunity of returning again into *f* through the pipe *i i*; and as the air from *e* escapes, its place will be occupied by a new charge of water, which will rise through the valve *g*, and again fill the lower chest *e*, and prepare it for a second discharge. All, therefore, that is necessary to keep the machine in action is to open the cocks *l* and *m* alternately, that is to say, to keep the cock *l* open as long as any water flows from the discharging pipe at *h c*, and as soon as the efflux ceases, to shut the cock *l*, and open *m* to discharge the water from *f*, and permit the lower chest *e* to fill, which will be effected whenever water ceases to flow from *m*. The cock *m* must then be shut, and *l* opened, and so on alternately, which may easily be done mechanically, and without superintendence, by using a part of the impelling water from *d*, or that which has been discharged from *h c*, and which may be employed to turn a small water-wheel, or to fill two small cisterns in which floats are made to act. Mr. John W. Boswell devised a contrivance for answering this same purpose, which will be found fully detailed in the second volume of Dr. Gregory's excellent *Treatise on Mechanics*, where this simple machine is described under several forms and modifications. It must not be supposed that filling the middle vessel *f* with water will discharge the whole of the water out of *e*, otherwise disappointment in its effects will ensue; because, although water is nearly incompressible, air is highly elastic, and the air in *e* will be compressed into less than its natural bulk, or will be condensed with a force equivalent to the pressure of the perpendicular column of water *h h*, which it has to overcome; and as atmospheric pressure was shown, when speaking of the pumps under the second head or division, to be only equal to the support of a column of water about 33 feet in height, so if we imagine this to be the height of the pipe *h h*, that column of water would require one of double atmospheric elasticity to support it, and hence the air in *e* will be condensed to half its former volume, and, therefore, discharge but half the volume of water, although *f* should be completely filled. Dr. Gregory further describes a curious phenomenon which takes place in the working of this machine, and which never fails to create surprise in the strangers who visit it, and to whom it is usually shown. That is, when the efflux at *h c* has stopped, if the cock *n* be opened, the water and air rush out together with prodigious violence, and the drops of water are changed into hail or lumps of ice, issuing with such force as frequently to pierce a hat if held against them, like pistol bullets. This rapid congelation is a remarkable instance of the general fact, that air, by suddenly expanding, generates cold, its capacity for heat being increased.

The *Water Ram*, or *Bélier Hydraulique*, as it was called by its inventor, M. Montgolfier, of Paris, is a highly useful and simple machine, for the purpose of raising water without the expenditure of any other force than that which is produced by the momentum or moving force of a part of the water that is to be raised. The effect of this machine depends entirely upon momentum, or the new quantity of force that is generated whenever a body is put into motion; and the effect of this is so great as to give the apparatus the appearance of acting in defiance of the established laws of hydrostatic equilibrium; for a moving column of small height is made to overcome and move another column much higher than itself. The form and construction of the hydraulic ram is shown in the figure on the next page. Suppose *o* to represent a reservoir, or the source of a spring, which is continually overflowing and running to waste by means of a channel a few feet lower than itself, as at the level line *p p*. Instead of permitting the water to flow over the sides of *o*, let it be conducted to the level of *p p* by means of pipes *q q* connected with the side of the reservoir, and terminating by an orifice *r*, in which a conical or other valve *s* is placed, so as to be capable of effectually closing the pipe when such valve is drawn upwards. *t* is an adjustable weight, fixed on the spindle of the valve *s*, by means of which the valve is kept down and open; any water, therefore, that is in the cistern *o* will

flow down the pipe *q q*, and escape at the orifice *r*, so long as the valve remains down; but the instant it is raised and shut, all motion of the water is suspended. Thus situated the adjustment of the weight *t* must take place, and by adding to, or subtracting from it, it must be made just so heavy as to be capable of sinking or forcing its way downwards against the upward pressure of the water, the force of which will depend upon the perpendicular distance from the surface of the water in *o*, to its point of discharge at *r* (represented by the dotted line *o v*); consequently, if the valve *s* be raised by the hand or otherwise, all motion



of the water in the pipe *q q* will cease, but the instant the valve is released, it will fall down and permit the water to escape. The water by its motion acquires momentum and new force, and consequently is no longer equal to the column *o v*, to which the valve has been adjusted, but is superior to it, by which it is enabled to overpower the resistance of the weight *t*, and it carries the valve up with it, and closes the orifice *r*. This is no sooner done than the water is constrained to become again stationary, by which the momentum is lost, and the valve and weight again become superior, and fall, thus reopening the orifice, and permitting the water to flow again; and as the pressure of the water and the weight of the valve each alternately preponderate, the valve is kept in a constant state of vibration, or of opening and shutting, without any external aid whatever. Such is the principle upon which the motion of the water in the pipe *q q* is produced; but the motion generated cannot be instantly annihilated; and it is not only of sufficient power to raise the valve *s*, but likewise to burst open the lower end of the pipe *q q*, unless a sufficient vent be provided, by which this accumulated force can escape. Accordingly a second valve *u* is placed near the lower end of these pipes, and is made to open upwards into an air vessel *w*, with a discharging pipe *x*, and, consequently, whenever the valve *s* is closed, the water which would otherwise have flowed from the orifice *r* now opens the valve *u* and enters the air vessel, until the spring of the contained air overcomes the gradually decreasing force of the momentum, when the valve *u* closes, and that at *s* opens to permit the water to make a second blow or pulsation, and in this way the action of the machine continues unceasingly, without any external aid, so long as it is supplied with water and remains in repair. A small running stream is necessary for this machine, as the water at *o* should be kept at one constant elevation to ensure the perfection of its action. A much greater quantity of water likewise escapes at the orifice *r* between the pulsations than can be raised in the delivery pipe *x*, particularly if it extend to any considerable height, for the comparative quantity of water discharged through *x*, and permitted to run to waste at *r*, must always depend upon the respective perpendicular heights of the pressing column *o v* and the delivered or resisting column *w x*, and the rapidity of the pulsations will likewise depend upon the same circumstances. Mr. Millington, from whose *Epitome of Natural Philosophy* the above description is taken, and who has erected several of these machines in different parts of England, which gave great satis-

faction, in order to show their efficacy gives the following particulars of one, which, at the time when he wrote, had been in constant use for about two years. The reservoir *o* is a basin of about 10 feet square and 2 feet deep, formed partly in limestone rock, and partly in brickwork, the supply of water being from a natural spring. The pipe *q q* is of cast iron, 14 yards long, and 2 inches in diameter. The piece at the end, containing the air vessel and the valves, is about fifteen inches long; the valves 1½ inch each in diameter, and made of brass; contents of the air vessel, about 1 gallon. The height from the surface of the water at *o* to its point of discharge at *r*, is 6 feet 4 inches, measured perpendicularly. The delivery pipe *x* is of lead, 1 inch in diameter, and proceeds horizontally under the ground 104 feet, and then rises perpendicularly to the height of 54 feet 3 inches above the discharge valve at *r*, where it delivers the water into a large cistern. The water is thus raised 47.11 inches above the surface of the spring which supplies it, and this by a fall of only 6 feet 4 inches. So circumstanced, the valve *s* makes about 50 vibrations, or opens 50 times in a minute, when it loses about two quarts of water, and injects nearly a quarter of a pint into the elevated cistern at each pulsation; the water lost being to that which is raised nearly as 17 to 1. This may appear a small quantity of water, but when it is recollected that the machine is at work night and day (unless purposely stopped), and furnishes six quarts of water every minute, this will be found to be a supply adequate to a very large household establishment. The construction above described is, however, incomplete, as, owing to the mutual incorporation which takes place between air and water, the successive quantities of water that are impelled into the air vessel would soon absorb the whole of the air contained in it, and it would cease to afford that elasticity which is indispensable to the working of the machine. This was discovered in France by M. Montgolfier, who added an improvement to the machine by introducing a very small shifting valve, opening inwards into the lower part of the air vessel, but kept shut by a small spring. This is shown in the separate shaded figure above the last described, and represents an improved form of the air vessel. This valve is self-acting, and effectually prevents the escape of any air or water from the air vessel; but when the water is thrown back by the shutting of the valve *s*, it produces an instantaneous vacuum at the end of the pipe *q*, upon which the shifting valve opens, and admits a sufficient quantity of the external air into the air vessel to keep it constantly replenished, and by this simple addition the water ram is rendered continuous in its action.

The cut on page 725 represents a machine for raising water, the invention of Mr. Rudolph Cabanal, engineer, of Melina-place, Westminster-road. It consists of a series of troughs fixed one above another in a frame-work, and so inclined in contrary directions that each trough is united at one of its ends with the trough next below it, and at the other end with the trough next above it. The lower part of this frame-work forms the segment of a circle, and rests upon a horizontal plane; so that with a very slight impulse the whole machine is put into a rocking motion; the lowest trough is thereby made to dip at each oscillation into a reservoir of water, which enters the trough through valves at the bottom; these opening only upwards, the water cannot return. As the next oscillation raises the end that was before depressed, the water runs along the trough to the opposite side of the machine, where it is discharged into the depressed end of the trough above it; from this second trough it is at the next oscillation thrown into the third trough; then from the third to the fourth at the following oscillation: in like manner it ascends each trough successively by the alternate rocking of the machine, until the water is raised and discharged at the required height. As the number of troughs, and the height of the machine, will depend upon the altitude to which it is required to raise the water, and as three troughs will show the arrangement and the action of the machine, as well as a greater number, we have, accordingly, reduced our diagrams to the exhibition of only three; these are shown at *a b c*, *Fig.* 1, attached to the framing *e e e e e*, with its curved segment *d* resting upon its horizontal plane *p*. It is necessary here to notice that the frame-work is double, that is, there are the same parts on this side the trough as are shown

in *Fig.* 1 on the opposite side, which will be better understood on reference to the plan *Fig.* 2, where one side of the parallelogram marked *e* (as in *Fig.* 1), corresponds with the opposite side marked *f*. Now it will be evident that when the lowest end marked *l* of the trough *a* is depressed, it will dip into the reservoir *g*, and, by the opening of the valves, receive the water as shown; the reverse motion of the machine, by which the end *m* is depressed, then causes

Fig. 1.

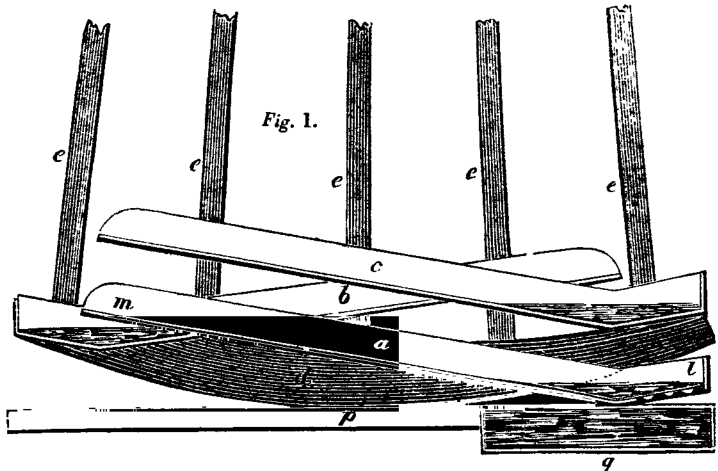
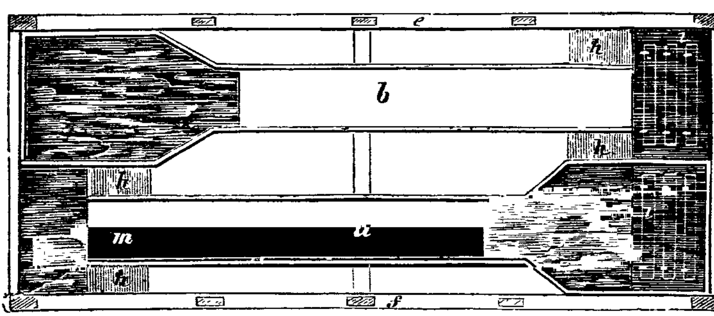


Fig. 2.

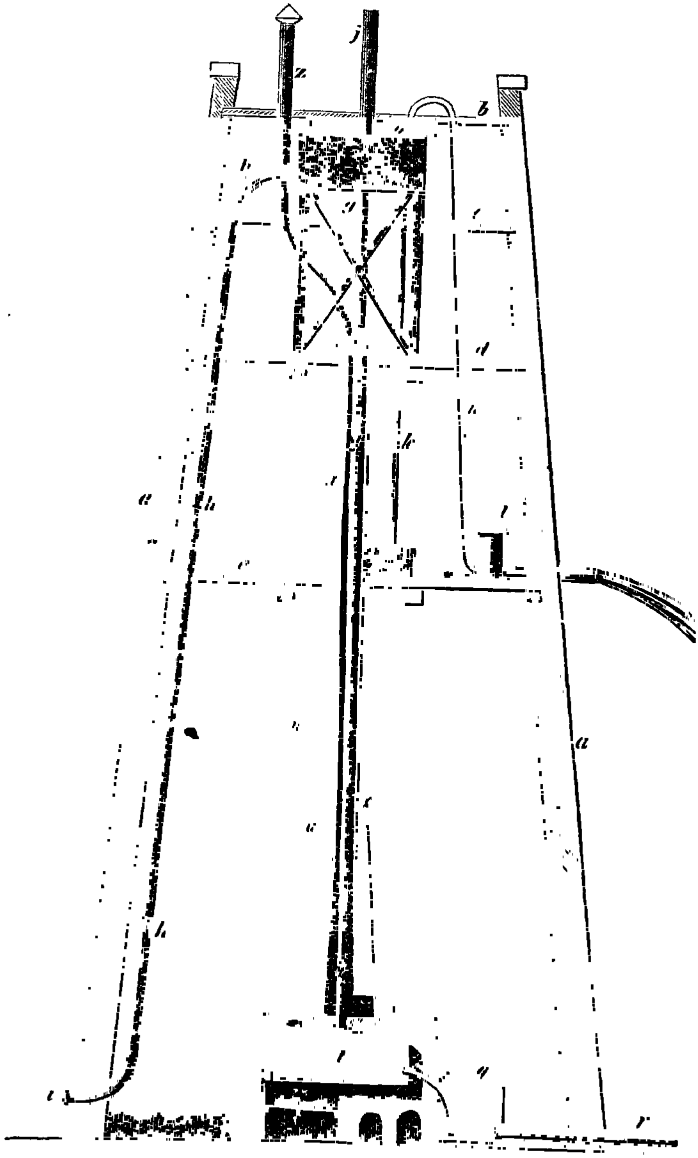


the water to run along *a* into *b*, and, at the next oscillation, from *b* to *c*, and so on into any number of troughs in succession. In the plan, *Fig.* 2, but two troughs could be shown; these are the lowest, all the others being of the same shape: *l l* is the depressed end of *a*, showing its long flap-valves, and that the water runs from one to the other under the partition that seems to divide them. The end *m* being depressed, the water flows in like manner into the double chamber of *b*, and from *b* it is discharged into *c*, which, being above *b*, cannot be shown in this plan. To the ends of each trough an inclined plane or board is fixed to prevent the water from splashing over it; these are shown at *h h* under the troughs *a b*. Contrivances of this kind are described in most of the old writers upon hydraulics; and in France, where they are known as the "water-balance," several curious constructions have been invented.

A patent was taken by Mr. A. Bernhard for a novel mode of raising water by the joint action of exhaustion, atmospheric pressure, heat, and condensation, to a height exceeding fifty feet, with the view of applying the fall from that

height as a motive power for impelling machinery. The water to be raised runs from its level into a cistern contiguous to the foundation of a large boiler; and from the latter proceeds downwards a curved pipe dipping into the cistern. At the top of the boiler there is another pipe, which leads shortly into a vertical pipe, upward of eighty feet in height, which the patentee terms the *hot water ascending pipe*. To preserve the temperature of the fluid in this pipe, the lowermost portion of it, to the extent of 30 feet, is inclosed in the brick flue of the furnace chimney; hence it is inclosed in an iron funnel pipe, which forms the remainder of the flue to the top of the building, which is a pyramidal tower 100 feet high. Near the top of the tower is a refrigeratory, formed by a judicious arrangement of two tiers of pipes placed horizontally in a *wooden* case; into these pipes the hot water in the ascending pipe (which here terminates by branching off from the flue) is discharged. Throughout the refrigeratory box, and surrounding the pipes, a current of cold air is continually passing; this is brought from the lowest part of the building through a large tube, and is discharged through another proceeding from the top of the refrigeratory, and extending to 25 feet above the altitude of the tower, to cause a strong draught. The effect of this current of air is to cool the hot water distributed in its pipes, from the lower tier of which it runs out and descends a vertical pipe 36 feet in length, whose lower extremity is turned up and immersed in a cistern of water to seal it from the air; this pipe the patentee calls the *cold water descending pipe;* the upper end of it communicates with the exhausting pipe of an air pump, which is used in the first place to obtain a partial vacuum in the pipes described, and afterwards to abstract the air disengaged from the hot water, during the progress of the operation. The reader will now perceive, that when the exhausting process is nearly completed by the working of the air-pump, the pressure of the atmosphere will force the water out of the cistern on the lowest level up the curved pipes mentioned, into the boiler, and filling the same, the water will rise up the vertical (*hot water ascending*) pipe, proceeding from the top of the boiler to the height of about 30 feet. This being effected, the patentee says that if heat be now applied to the boiler, the water will thereby be made to rise 50 feet higher into the refrigeratory. Here, being distributed in the small pipes, it is cooled, and descends to the cold water pipe, wherein the pressure of the column of water being greater than that of the atmosphere, the water will run out over the cistern, and will continue to do so until the equilibrium is restored, which it is the object of the patentee to prevent, and thus obtain a constant power by the fall of the water from the cistern. Having so far explained the object of the patentee, and the principle upon which he intends to operate, we shall now describe the apparatus more particularly with reference to the engraving on the next page, which is merely a diagram of the apparatus, as complete drawings of it would require several figures. *a a* represent the walls of the building; *b c d e* four floors in the same; *f* the refrigeratory, which communicates with the hot water ascending-pipe *g; h h* is the air-tube, which receives its supply at *i*, and after blowing through the refrigeratory, escapes by the tube *j*, which extends 25 feet above the tower (but is shown, for want of room, as broken off); the water in the refrigeratory is prevented from returning by the intervention of a valve, and after being cooled in passing through the series of pipes, runs down the pipe *k;* at *l* is the air-pump with the pipe *n*, which connects it with the top of the pipe *k*, through the medium of which the other pipes are exhausted; *q* is the reservoir which receives the water upon the natural level by a channel as at *r;* the operation of the air-pump causes the water to rise up the pipe *s* into the boiler *t*, thence up the pipe *g* as high as the dotted line *u*, after which, heat being applied to the boiler by the furnace *v*, the hot water rises to the refrigeratory. About midway of the pipe *g* there is a stuffing-box at one of the junctures to allow of the expansion and contraction of the metal by changes of temperature. The pipe *g* is shown as extending vertically through the brick chimney up to *w*, thence through the flue *x* to the box *y;* hence it proceeds to the refrigeratory, and the flue-pipe takes a bend as at *r*, and proceeds to the top of the building. To prove the truth of the principle, the patentee erected an apparatus on a considerable scale

in the Kent Road, near Peckham, but the result was a complete failure; and even had it been practicable, we doubt much whether it would have been an



economical mode of raising water to that height, when we consider the fuel that must be expended to raise the temperature of the water, and the power required to work the air-pump.

HYDRAULICON, OR WATER ORGAN. A musical instrument acted upon by water; the invention of which is said to be of higher antiquity than that of the wind organ.

HYDRIODATES. Salts consisting of hydriodic acid, combined in definite proportions with oxides.

HYDROCHLORIC ACID. A compound of chlorine and hydrogen.

HYDROCYANIC ACID. Prussic acid; which see.

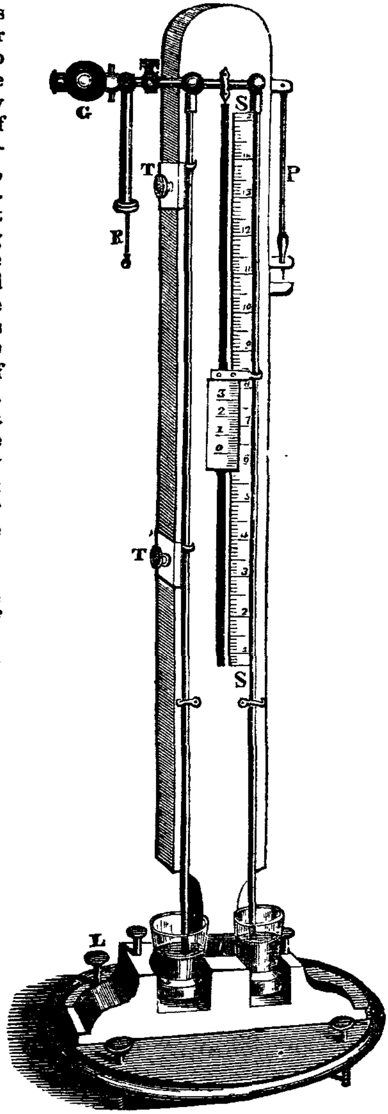
HYDRODYNAMICS treats of the mechanical properties of fluids in general. It is usually divided into hydrostatics, which explains the pressure and equilibrium of liquids, such as oil, water, &c.;—Hydraulics, which points out the laws and effects resulting from the motions of liquids;—and Pneumatics, or the doctrine of elastic fluids or gases, as steam, air, &c.

HYDROGEN GAS. See CHEMISTRY.

HYDROMETER. An instrument for ascertaining the specific gravities of different liquids. The most common description of these instruments consists of a hollow ball, of either metal or glass, capable of floating in any known liquid, and having two stems, the lower one terminating in a weight, in order that the instrument may float with the stems upright, and the upper stem (which is of the same diameter throughout), being graduated, to show the density of the fluid by the depth to which it sinks; as the heavier fluids will buoy up the instrument more than such as are lighter. In this way, however, it is clear that the stem must be of considerable thickness, in order that the instrument may have an extensive range, in which case the smaller differences of density will not be perceptible. To obviate this imperfection various contrivances have been resorted to; one of the most common of which is, to construct the instrument as above described, but with a very slender stem, which is divided into 100 equal parts; and to provide a number of movable rings, all of equal weight, any one of which being slipped over the stem, when the instrument floats in distilled water with zero on the stem at the surface of the water, will cause it to descend until the top of the scale be at the surface; and the density is estimated by the number of weights required to bring the lower part of the scale below the surface, minus the number of divisions of the scale which remain above the surface. But the method of Fahrenheit is both simpler and more accurate. The hydrometer of Fahrenheit consists of a hollow ball with a counterpoise below, and a very slender stem above, terminating in a small dish. The middle or half length (the stem,) is distinguished by a fine line across, and the instrument is always immersed up to this line by placing weights in the little dish above. Then as the part immersed is constantly of the same magnitude, and the whole weight of the hydrometer is known, this last weight added to the weights in the dish will be equal to the weight of fluid displaced; and if the gravity of water be represented by 1000, and the weight be divided into thousandth parts of the weight of the instrument when it sinks to the middle of the stem in distilled water, the number of weights required to sink the instrument to the mark on the stem when floating in any fluid, added to the weight of the instrument, or 1000, will represent the specific gravity of the fluid.

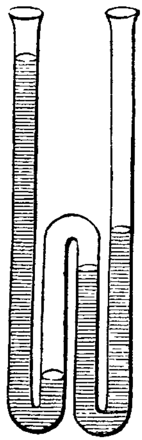
The engraving on the following page represents an instrument for ascertaining specific gravities, invented by Dr. Hare, Professor of Chemistry in the University of Pennsylvania. This instrument, to which the inventor has given the name of Litrameter, owes its efficiency to the principle, that when columns of different liquids are elevated by the same pressure, their heights must be inversely as their gravities. Two glass tubes, of the size and bore usually employed in barometers, are made to communicate internally with each other, and with a gum elastic bag G, by means of a brass tube, and two sockets of the same metal, into which they are severally inserted. The brass tube terminates in a cock, in which the neck of the bag is tied. Between the cock and the glass tubes there is a tube at right angles to an opening into that which connects them. At the lower end of this tube, a small copper rod R enters through a collar of leather. The tubes are placed vertically in grooves, against an upright strip of wood, tenonned into a pedestal of the same material. Parallel to one of the grooves, in which the tubes are situated, a strip of brass is fastened, and graduated, so that each degree may be equal to $\frac{1}{250}$ of the whole height of the tubes. The brass plate is long enough to admit of about

140°. Close to this scale a vernier *v* is made to slide, so that the divisions of the scale are susceptible of sub-division into tenths, and the whole height of the tubes into about 2200 parts or degrees. On the left side of the tube there is another strip of brass, with another set of numbers, so situated as to comprise two degrees of the scale above mentioned, in one. Agreeably to this enumeration the height of the tubes is, by the aid of a correspondent graduation on the vernier, divided into 1100 parts or degrees. A small strip of sheet-tin *k* is let into a kerf in the wood, supporting the tubes, in order to indicate the commencement of the scale; and the depth to which the orifices of the tubes must extend. At distances from this of 1000 parts and 2000 parts, (commensurate with those of the scale,) there are two other indices, T T, to the right hand tube. Let a small vessel containing water be made to receive the lower end of the tube, by the side of which the scale is situated; and a similar vessel of any other fluid, whose gravity is sought, be made to receive the lower end of the other tube; so that the end of the one tube may be covered by the liquid in question, and the end of the other tube by the water. The bag being compressed, a great part of the contained air is expelled through the tubes, and rises through the liquid in the tumblers. When the bag is allowed to resume its shape, the consequent rarefaction allows the liquids to rise into the tubes, in obedience to the greater pressure of the atmosphere without. If the liquid to be assayed be heavier than water (as, for instance, let it be concentrated sulphuric acid,) it should be raised a little above the first index, at the distance of 1000 degrees from the common level of the orifices of the tubes. The vessels holding the liquids being then removed, so that the result may be uninfluenced by any inequality in the height of the liquids, the column of acid must be lowered, until its upper surface coincide exactly with the index 1000. Opposite the upper surface of the column of water the two first numbers of specific gravity of the acid will then be found; and, by duly adjusting and inspecting the vernier, the third figure will be ascertained. The liquids should be at the temperature of 60°. If the liquid under examination be lighter than water, as in the case of pure alcohol, it must be raised to the upper index. The column of water, measured by the scale of 1000, will then be found at 800 nearly; which shows that 1000 parts of alcohol are, in weight, equivalent to 800 parts of water; or, in



other words, 800 is ascertained to be the specific gravity of the alcohol. The sliding rod and tube at *r*, between the cock and the glass tubes, facilitates the adjustment to the index of the column of liquid in the right hand glass tube. When the rod is pushed in as far as possible, it causes a small leak, by which the air enters; and the columns of the liquids, previously raised too high by the bag, may be allowed to fall, till the liquid which is to be assayed is near the index; then, by pushing the rod in, they may be gradually lowered, and adjusted to the proper height, with great accuracy. A rod of this kind, graduated, might answer the purpose of a vernier.

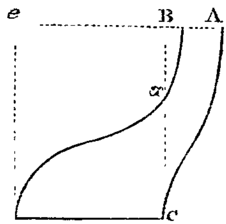
Meikles' Syphon Hydrometer, represented in the annexed engraving, it will be seen, is upon this same principle, but of a much simpler construction. This instrument consists of a glass tube, open at both ends, and bent into a kind of double syphon, having four parallel legs; so that the open ends are pointed in the same direction, or upwards, as in the annexed engraving. The manner of using it is very simple: let one of the ends be stopped with a finger or cock, and water be poured into the other. The fluid will only rise a small way into the second leg, because of the included air: next, stop the other orifice, and open the one first closed; and having poured into the latter the liquid whose specific gravity is to be tried, open the top of the water tube; then the instrument being held upright, the two liquids will arrange themselves so as to press equally on the included air. This pressure will be measured by the difference in the heights of the two columns of either liquids multiplied by its specific gravity, so that by dividing the difference of the two columns of water by the difference of those of the other liquid, we obtain the specific gravity of the latter; that of water being unity. The difference between the columns may be measured by applying any scale of small equal parts, or the glass may be attached to a graduated plate furnished with verniers, &c. The longer the columns of liquid employed, the more accurate the process. The expansion of the glass or its capillary action cannot affect the result, nor is it influenced by the expansion of the scale; the only correction required will be to reduce the observations to one temperature.

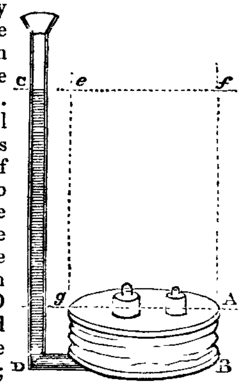


HYDROPHANE. A variety of opal, which has the property of becoming transparent on immersion in water. It is also called *oculus mundi.* We must be careful to immerse them only in pure water, and to withdraw them whenever they have acquired their full transparency. If we neglect these precautions, the pores will soon become filled with earthy particles, deposited from the water, and the hydrophane will cease to exhibit this curious property, and will remain always more or less opaque.

HYDROSTATICS explains the pressure and equilibrium of liquids, or of what have been generally termed inelastic fluids. A fluid is a body whose parts are put into motion among one another by the slightest force, and which return to their former state as soon as the impressed force is removed. Fluids have been divided into elastic and inelastic; but recent experiments have proved that there is no fluid that may not be compressed by a sufficient force, and that will not return to its former state when the compressing force is withdrawn. The terms may, however, without much inconvenience, be retained, as the difference in compressibility is so great, that a sufficient distinction obtains. Thus the same power that would reduce air to one half of its former dimensions would effect a compression not exceeding one twenty-thousandth of its bulk in water. Hydrostatics, then, is concerned with those fluids, the compressibility of which may, for most practical purposes, be considered as inappreciable. The laws of this science are generally proved by experiments on water, as a fluid that is most plentiful, and most easily adapted to the purpose. The principal and most important propositions with respect to pressure are,—1. That fluids press equally in all directions. 2. That in fluids of equal density the pressure is proportional to the perpendicular distance from the surface. That fluids press equally in all directions is seen in a variety of cases, and may

therefore be easily made evident. If a cylindrical tin vessel have two holes of equal size, one in the bottom and the other in the side as near the bottom as may be, it will be found that each of these holes will permit the contents of the vessel to run out in equal times. Now as the velocity of the running water is dependent upon the pressure, it is manifest that the pressure upon the side, or *lateral* pressure, is equal to that on the bottom, or downward pressure. That the upward pressure is also equal is inferred from the fact, that water poured into one of the legs of a bent tube will rise to an equal height in the other leg. This upward pressure is a feature that distinguishes fluids from solids, and is due to the extreme mobility of its particles, owing to the repulsive energy which is exerted when the least compressing force is applied. We have next to show that the pressure upon any particle in a fluid is proportional to its perpendicular depth. In the annexed diagram, if x be a particle of water, the pressure exercised upon it will be proportional to the depth B x; for if a hole were made at x, the fluid (making allowance for the resistance of the air) would spout up to A e. In like manner the pressure at C is equal to the perpendicular depth B C; and as every particle on the bottom is at an equal depth, the whole pressure will be equal to that produced by a column filling the whole space B C D e. From this it appears that the pressure on the bottom of a vessel is equal to the area of the base multiplied by its perpendicular height. In vessels having equal bases the pressure will be proportional to the height, and in vessels of equal depths the pressure will be as the area of their bases, and this without any regard to the quantity of fluid employed. This has given rise to the hydrostatic paradox—"that any given quantity of water, however small, may be made to balance any other quantity, however large." Also the hydrostatic bellows depend on the same principle. In the cut, A and B are two circular boards connected by leather after the manner of a pair of bellows, so as to be water-tight. A tube, C D, is made to communicate with the interior. If a small quantity of water be now poured in so as to separate the boards, and a number of heavy weights be placed upon the upper board, the water in the tube C D will be seen to rise till it balance the weights placed upon A. If the quantity of water in the tube, above the level A g, be noticed, it will be found to be so much less than the weights upon A, as the area of the bore of the tube falls short of the area of the board A. To make the subject more evident, let us suppose the sectional area of the tube C D to be half a square inch, and that of the lower board of the bellows to be one square foot, or 288 times greater; it will then be found that one pound of water in the tube C D will support a weight of 288 pounds on the board A g. In a similar way, a long narrow tube may be inserted perpendicularly into a cask or other vessel; after the vessel has been filled, a few ounces of water poured into the tube will burst it. If a fissure in a rock should communicate with an internal cavity of considerable magnitude, situated at some depth below the top of the fissure, and filled with water, the pressure may be so enormous as to burst the rock. The same effect may be produced by rain falling into, and filling a long slender chink that may have been left in the walls of a building; whether the chink is of equal diameter throughout, or vary in its size, and whether it be straight or crooked, provided it be water-tight, so as to get full of rain, the effect will be the same, the pressure being always proportionate to the perpendicular height. This principle has been ingeniously applied by the late Mr. Bramah, in what is termed the Hydrostatic Press, a machine by which an almost incredible force may be obtained in a





very small compass. (See *Bramah's Press*). From the equal pressure in all directions arises the tendency in fluids to find their own level, so that the surface of every fluid at rest is horizontal; and for a similar reason, if two fluids be in the same vessel, and do not mix, their common surface will be parallel to the horizon. From what has been stated on the nature of fluid pressure, it will be easy to calculate the pressure on any horizontal surface. Thus, if a cubical vessel be filled with water, the pressure on the base will be equal to the weight of the fluid. The same pressure will obtain if the vessel be of a conical form, provided the area of the base and the height be the same. The pressure upon a perpendicular surface will of course vary with the depth. If a board one foot square be placed perpendicularly in a vessel of water, and be divided into horizontal sections, each one inch deep, then calling the pressure at the depth of one inch 1, the pressure at two inches will be 2, at three inches 3, and so on; hence the whole pressure will be equal to the sum of the series 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12: this will amount to half the pressure which would have occurred if the board had been situated horizontally 12 inches below the surface. Now, as the centre of gravity of this surface is situated in the middle of the board, it follows that the area of the board, multiplied by the distance of its centre of gravity beneath the surface, will be equal to the pressure. From a more extended investigation it is found that this rule is general, that the pressure of a fluid against any surface, in a direction perpendicular to it, varies as the area of the surface multiplied into the depth of its centre of gravity. From this we see that the pressure against the four sides and bottom of a cubical vessel is equal to three times the weight of the contained fluid. From this also may be calculated the pressure on dock gates, on the lower parts of ships, and large cisterns, coolers, &c. In all cases of pressure the amount, as determined above, must be multiplied by the specific gravity of the fluid employed, as it will be evident, that if two vessels of equal sizes and similar shapes be filled, one with water, and the other with mercury, that the pressure on the base of the latter will be so much greater than that on the former, as the weight of the mercury exceeds that of the water.

The equal pressure in all directions causes the surface of all large bodies of water to be horizontal, and also the surfaces of any two bodies of water communicating by a tube or otherwise; hence the construction of water levels. In the annexed cut A B is a tube turned up at each end, and filled with mercury or water. Upon the surface of the fluid at *c* and *d* are small floats, carrying an upright sight, with a horizontal wire or hair across it. When the instrument is held in the hand, on looking through *c* its cross wire will cover that of *d*, because the fluid stands equally high in both legs. If it be required to know whether any distant object be horizontal, it is only necessary to point the instrument toward it; and if the two cross wires and the object coincide, the object is in the same horizontal line. The common spirit level consists of a small tube filled with spirits of wine, except a small space, which contains a bubble of air. The tube is hermetically sealed; and when placed on a horizontal surface, the bubble will be seen in the middle of the tube. A little reflection on the nature of hydrostatic pressure will show its applicability to the purpose of ascertaining the comparative weights of bodies, or, what is commonly termed their specific gravities. If a body of any shape, either as heavy as water, or heavier than it, be plunged into a vessel filled with that liquid, it will of course displace a quantity of fluid equal to its own bulk, and if the quantity be measured, we have a ready measurement of the magnitude of the solid body that was immersed; for as the water displaced is equal in bulk to the size of the irregular solid, a measurement of the one will serve to ascertain the other. Again, if the quantity displaced be weighed, and the immersed solid weighed also, we shall have the relative weights of the two substances, or their specific gravities. If the whole of the water displaced could be accurately collected and weighed, this method would furnish a ready mode of ascertaining the relative weights of any two bodies. Thus, if two

bodies of equal weight, successively plunged into water, were to displace one and two ounces of water respectively, the relative weights of the bodies would be as 2 to 1. As, however, considerable difficulty would arise in the use of this method, the following process is used with bodies heavier than water. Weigh the body in air, and also in water, observe how much of its weight it loses by immersion in the water, and then divide the weight of the body in air by the loss in water. Suppose a piece of gold to weigh 58 grains, by weighing it immersed in water it would lose 3 grains of its weight; divide the 58 grains by 3, and it will give $19\frac{1}{3}$ as the specific gravity of gold; that is, the gold would be $19\frac{1}{3}$ times heavier than an equal bulk of water. The weights of solid and liquid bodies are usually compared with that of water, one cubic foot of which contains just 1000 ounces avoirdupoise. Hence, by referring to tables of specific gravities, we obtain the real as well as the relative weights of bodies. Thus, in the example we have given, a cubic foot of gold would weigh $1000 \times 19\frac{1}{3} = 19{,}333$ ounces. If the solid consist of a substance that is soluble in water, it must be covered with a coating of wax or varnish, and an allowance made for the difference produced by the coating. When the solid consists of several small pieces, a cup must be previously immersed in the water, and accurately counterpoised; the fragments may then be placed in it, and the loss of weight ascertained. If the body whose specific gravity is required be lighter than water, another heavier body must be attached to it, and the loss of weight in the compound being noticed, the loss in the heavier body must be subtracted from it, and it will give the loss of weight in the body under investigation. The specific gravity of liquids is found by filling a small bottle (which holds a definite quantity, say 1000 grains of water,) with the liquid under examination, and then weighing the quantity contained, the proportion which this bears to 1000 is the specific gravity of the liquid. Thus, if the bottle be successively filled with water, real alcohol, and nitric ether, the weight of the equal measures would be 1000, 797, and 908, which represent the specific gravities of these fluids. This experiment shows clearly the nature of specific gravity, which it will be seen is simply obtaining the real weights of equal measures of different substances. If we could obtain a cylinder or cube of copper, and another of gold, of exactly the same dimensions, and compare their true weights with the weight of a portion of water of the same magnitude, we should at once obtain their relative or specific gravities; but as it is inconvenient to alter the shapes of bodies, and, in many cases, would be next to impossible to obtain them of precisely the same dimensions, the usual mode of weighing in water, by which we obtain the weight of a quantity of water of equal bulk with the solid, is infinitely preferable. For further information on the subject of this article see Bramah's Press, Hydrometer, Specific Gravity, &c.

HYDROSULPHURETS. Compounds of sulphuretted hydrogen with the salifiable bases.

HYDRURETS, compounds of hydrogen with metals.

HYGROMETER. An instrument for ascertaining the degrees of dryness or moisture of the atmosphere; therefore whatever substance expands by moisture or contracts by dryness, may be employed for the purpose, in connexion with a suitable index and scale, showing the changes it undergoes. The hygrometer invented by Saussure consisted of a hair, divested of its oil by boiling it in water containing one per cent. of sulphate of soda. One of the ends of the hair was attached to a fixed point, and the other to the circumference of a movable cylinder, that carries a light index; the hair being kept straight by a counterweight of three grains, suspended by a fine silk thread to the cylinder, and wound thereon the contrary way of the hair. As the hair lengthens or shortens by changes in the humidity of the air, the cylinder is put in motion, and the index fixed thereto points out on a graduated circle the degree. This pretty little contrivance of Saussure's was regarded as a faithful indicator of the true condition of the atmosphere until M. de Luc proved that hair was incapable of becoming a correct measurer of humidity, and that this was owing to its organic reticular structure. The last mentioned philosopher made an hygrometer, in which ivory was employed as the

medium of exhibiting the change of humidity. As ivory expands by moisture and contracts by dryness, he formed a very thin hollow cylinder of this substance, open only at the upper end, into which he fitted the open end of a very fine long glass tube, like that of a thermometer. Into these he introduced a quantity of quicksilver, filling the ivory cylinder, and a part of the glass tube. The consequence is this; when moisture swells the ivory cylinder, its capacity increases, and the mercury sinks in the glass tube; and *vice versâ*, when the air is drier, the ivory contracts, and forces the mercury higher up the glass tube. As this instrument is susceptible of being influenced by heat and cold, like the thermometer, as well as by that of humidity, its indications are not to be depended upon. Hygrometers are constructed, in a great variety of ways, by means of sponge, and a rod suspended like a scale-beam. The rod is to have one of its ends pointed, to serve as an index, and at the other end a hook to which the sponge is fastened. The sponge is prepared by first washing it thoroughly in clean water, and when it is dry washing it again in either water or vinegar, in which a quantity of salt of tartar or sal-ammoniac has been dissolved; after which, the sponge being well dried, is fit for use. Then having fixed against that part of a wall over which the point of the index will traverse, a graduated circular arc, the index will show on this scale the state of the atmosphere; for when the air is humid, the sponge will imbibe moisture from it, become heavier, and consequently pull that arm to which it is suspended downwards; while the other arm or index will move upwards, along the graduated arc on the wall. On the contrary, when the air becomes drier, it imbibes the moisture from the sponge, which consequently becoming lighter, the index preponderates, and moves down the graduated arc, thus showing the moisture or dryness of the atmosphere. Instead of the sponge, Mr. Gould recommends oil of vitriol, which grows sensibly heavier or lighter, as the moisture of the air increases or decreases; so that being saturated in the dampest weather, it retains, loses, or resumes its acquired weight, with the continuation, decrease, or increase of the moisture in the air. So great is the alteration in the weight of this liquor from the above cause, that in the space of fifty-seven days, it has been known to change its weight from three to nine drams, and has shifted the tongue of a balance thirty degrees. The curious on the subject of hygrometers may meet with a great multiplicity of them in the *Philosophical Transactions*, and the various scientific journals.

HYOSCIAMA. A new vegetable alkali, extracted by Dr. Brande from the hyoscyamus nigra, or henbane. It is a strong poison. The vapour is extremely prejudicial to the eyes; the smallest morsel of the alkali upon the tongue is dangerous. Nevertheless preparations of it are very advantageous, given in medicine, by eminent practitioners.

HYPERBOLA, is one of the conic sections, formed by the intersection of a plane and cone, when the plane makes a greater angle with the base of the cone than that formed by the base and side of the cone.

HYPOTHENUSE, the longest side of a right-angled triangle.

I.

ICE. Water in a solid, crystallized state, owing to the abstraction of its combined heat. Its specific gravity, according to Dr. Thomson, is .92. The force of expansion exerted by water in the act of freezing has been found irresistible in all mechanical experiments to prevent it. Advantage of this wonderful phenomenon is taken to burst bomb shells, and other massive vessels, by filling them with water, plugging them up, and then exposing them to the frost. The effects of this expansive force are often observable by the bursting of trees, and the rending of rocks, attended with a noise resembling the explosion of confined gunpowder. Water after being long kept boiling, affords an ice more solid, and with fewer air bubbles, than that which is formed from unboiled water; also pure water, kept for a long time in vacuo, and afterwards frozen there, freezes much sooner than common water exposed to the same degree of cold in the open atmosphere; and the ice formed of water thus divested of its air, is much

more hard, solid, heavy, and transparent, than common ice. Ice after it is formed, continues to expand by decrease of temperature; to which fact is probably attributable the occasional splitting and breaking up of the ice of ponds during the time of freezing, and sometimes, independent of other causes, the separation of icebergs from the great frozen continent at the poles. According to Dr. Black, ice requires 147 degrees of heat to reduce it to a fluid.

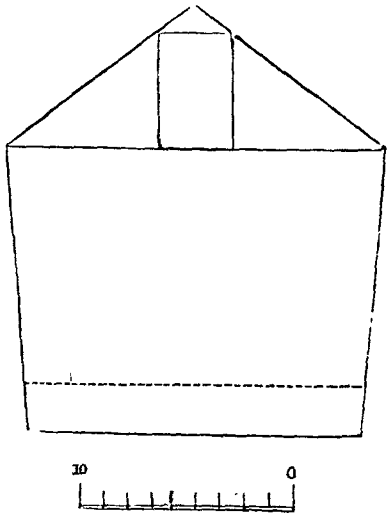
ICE-BOATS. There are two descriptions of boats which come under this denomination; namely, those that are designed to sail upon the surface of the ice, and those that are employed to open the navigation of frozen rivers or canals, by breaking up the ice. The first-mentioned kind of boats is much used in Holland, on the river Maeze and the lake Y. These ice-boats are propelled, it is said, with incredible swiftness, sometimes so quick as to render respiration difficult; they are found very useful in conveying goods and passengers over lakes and great rivers in that country. For this purpose a boat is fixed transversely over a thick plank, or three-inch deal, under which, at the extremities, are fixed irons, turned up forwards, resembling and operating as skates; upon this board the boat rests, with its keel at right angles to it; and the extremities of the boards serve as out-riggers to prevent the boat from upsetting, whence, therefore, ropes are fastened that lead to the head of the masts, in the nature of shrouds, and others passed through a block across the bowsprit. The rudder is made somewhat like a hatchet, with the edge placed downwards, which, being pressed down, cuts the ice, and serves all the purposes of a rudder in the water, by enabling the helmsman to steer, tack, &c.

The other kind of ice-boat alluded to, is a strong and heavy-laden canal-boat, fitted up for the purpose of breaking the ice, by arming the fore-part of the keel and the bows with iron, which penetrate and break down the ice as the boat is drawn forcibly along by an adequate number of horses towing it on the path. This measure of opening the navigation of a canal is seldom adopted, except when the ice is only a few inches in thickness, or when a thaw has rendered thicker ice of little tenacity.

ICE-CREAM. A species of confectionary made by immersing cream, variously flavoured, in a mass of ice, contained in a pail constructed for the purpose, wherein the cream is congealed.

ICE-HOUSE. A repository for ice during the summer season. In London and other places, ice is kept by the confectioners in deep cellars, from which the external air is excluded as much as possible, and provided with drains to keep them dry. When the surrounding soil is moist, a frame-work, or case of carpentry is constructed, having a grating at bottom, and is so placed in the cellar as to be two or more feet distant from the floor, sides, and roof of the cellar. In this the ice is said to be as perfectly preserved as in a dry cellar. Some market-gardeners preserve ice in great heaps, by merely building it upon an elevated base in the open garden, and covering it over and around by a very thick stratum of straw or reeds. This plan of preserving ice is in accordance with Mr. Cobbett's recommendation in his *Cottage Economy*, wherein he observes that "an ice-house should not be underground, nor shaded by trees, but be exposed to the sun and air;" that its bed should be three feet above the level of the ground, and composed of something that will admit of the drippings flowing instantly

form of the building may be varied according to circumstances; but in the well or receptacle for the ice, it is desirable to have sufficient room for the deposit of two or three years' consumption, as a provision against mild winters. Where the situation is of a dry, chalky, gravelly, or sandy kind, the pit may be entirely below the surface of the ground; in which case, an ice-house on the plan recommended by the late Mr. David Gordon (which was considered by that gentleman as an improvement upon the American and Italian methods) may be advantageously introduced, of which the annexed sketch represents an elevation.

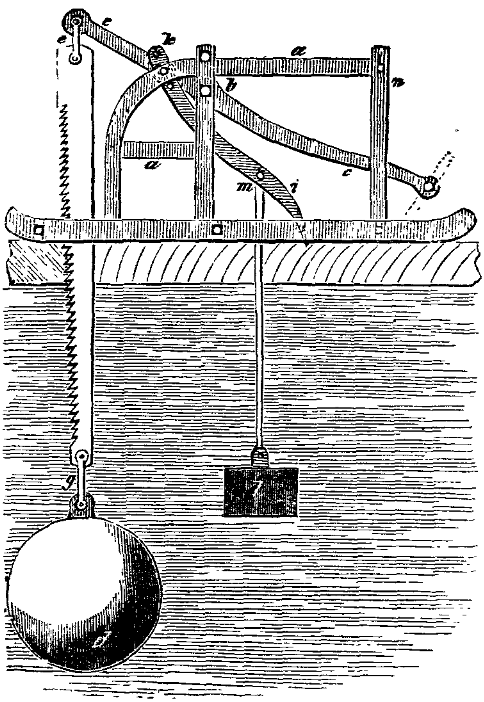


Dig a pit of about 12 feet deep, and wide enough to permit the erection therein of a frame of rough wood posts. This frame is to be 14 feet wide each way at the bottom, and 16 feet each way at the top, conformably to the sketch. The posts may be about 9 inches in diameter, placed near enough to each other for thin laths to be nailed upon them, and the inside be dressed to an acute angle, so that as little wood as possible may touch the ice. On the inside let thin laths be nailed at about two feet apart. On the outside, at moderate distances, nail rough boards, and fill the place within with wheat, or rye straw set on end. The inside of the roof to be made in the same way, and also the gables. Straw is to be sewed on the inside, and heath or straw on the outside of the door. The outside of the roof is to be thickly thatched with straw or heath; and heath, brushwood, or fir tops, to be filled in between the outside boarding and the surrounding ground, and then neatly thatched or turfed over. The bottom of the house, for two feet deep, should be laid with large logs or stones, next with heath, fir-tops, or brushwood, and then with straw. The ice-house thus completed, will look like a square bee-hive inverted, and is then ready to receive the ice or snow. But unless the house be in a very shady place, Mr. Gordon observes, it may be necessary to extend the roof, where the door is placed, five or six feet, making a second gable and door, finished in the same way as the first, and fill up the intervening space, except a passage, with heath or straw.

Mode of filling the house.—When the ice (or snow, if ice cannot be procured,) is put into the house, it must be well beaten down with a pavior's rammer, or mallet, and the surface *always kept concave*, as by this means any snow or ice that may melt will run to the middle, or interstices, and freeze. For the same reason, the ice ought always to be kept concave when it is taken out for use. Should the frost be very intense when the ice-house is getting filled, it may be very beneficial at the close of each day's filling to throw in thirty or forty pails of water, which will fill the interstices and freeze. When the house is full, spread upon the concave surface a carpet, or sail split up the middle, and upon the top thereof a foot thick of water. When ice is required for the use of the family, or when it is necessary to put in fresh meat to lie on the face of the ice for preservation, or to take out for use, the straw and carpet, or sail, is to be opened in the middle. Should rats infest the place, an iron-wire frame or case may be required to put the meat or fish, &c. into when lying on the ice. A small open surface-drain ought to be dug round the house, to prevent any water running into it. Opening the door of the house does little harm. Damp or dense substances touching the ice is much more prejudicial than dry air.

ICE-SAWS. Large saws used for cutting through the ice for relieving ships when frozen up. The vessels employed in the Greenland fisheries, and others that navigate the polar seas, are regularly furnished with these machines, as the lives of the crew not unfrequently depend on the expedition with which a passage can be cut, so as to disengage the vessel before the further accumulation of ice renders it an impossible undertaking. The saw, with a weight suspended to it, is introduced by means of a hole broken through the ice, and is suspended by a rope passed over a pulley fixed to a triangle. A party of a dozen or more men, run out and back again with a rope, and thus move the saw up and down till it has cut its way so far as to hang perpendicularly from the pulley. The triangle is then moved a foot or two farther, and the sawing recommences, the services of the whole crew being required in this laborious undertaking.

Lieut. W. J. Hood, of the *Hyperion*, R.N. has recently greatly improved this apparatus; for the communication of which and the presentation of an illustrative model to the Society of Arts, that gentleman was awarded the Society's honorary medal. In Mr. Hood's machine, the saw is suspended by a slight sledge, and is worked by the power of only two or three men at the end of a lever; a bar, called a propeller, is fixed on the lever between the fulcrum and the saw, the other end resting on the surface of the ice, and so adjusted that each motion of the lever shall produce a cut of a given length, and at the same time, by means of the propeller, push the sledge on, so that the teeth of the saw shall always be in contact with the ice. The annexed figure



gives a side elevation of the machine. *a a a* is a sledge, of open frame-work, resting on the surface of the ice; *b* a transverse bar passing through the lever *c c*, and forming the fulcrum on which it moves; this lever has a cross handle, as

represented in perspective in dotted lines; *e* a clamp or brace consisting of two cheeks, one on each side of the lever, loosely pinned at top to the lever, and at bottom to the saw *f*; *g* a clamp similar to *e*, by which the weight *d* (which is of the shape of a double convex lens) is hung to the lower end of the saw; *i* the propeller, an iron bar, terminating below in two claws, and at top in a fork, and suspended on the lever by means of a transverse pin *k*; *l* a weight hung to the propeller at *m*; *n* a transverse bar, limiting the motion of the handle end of the lever in an upward direction. It should be understood that there is a duplicate frame similar to that brought into view, on the other side of the machine, about 18 inches apart, and connected by transverse bars. To prevent the lever from swerving laterally, there are at the handle ends two upright bars, between which the lever moves. The saw, after having once entered the ice, will only require from two to four men to work it; and it should not be taken out of the ice till after the distance required to be cut through is accomplished. The saw can be guided by the lever in any direction, so as to cut the ice into pieces most convenient for removal, either by pushing them under the adjacent floor of ice, or by dragging them out of the ship's track into clear water.

ICHNOGRAPHY, in Drawing, is synonymous with the term *plan*, such as is exhibited in an horizontal section of a building, or of any other object, which shows the true dimensions to a scale of every part in the line or plane through which the section is made.

IGNITION, in its general sense, properly signifies the setting fire to any substance. But the sense is more usually limited to the kind of burning which is not accompanied with flame, such as that of metals, stones, and other substances, which become red hot without melting.

ILLUMINATING. A kind of miniature painting, anciently much practised for illustrating and adorning books, but now, comparatively to the other modes of illustration, but little practised, being chiefly confined to very expensive publications, of which a very few copies are intended to be taken, or to the adornment of manuscripts. Formerly, besides the writers of books, there were artists whose profession was to ornament and paint manuscripts, who were called illuminators. The writers of books first finished their part, and the illuminators embellished them with ornamented letters and paintings. In old manuscripts blanks are frequently found, which were left for the illuminators, who never filled them up. Some of the ancient manuscripts are gilt and burnished in a style superior to later times, and the colours are so excellent, as to indicate the exercise of great skill in preparing them.

IMPACT, in Mechanics, the simple or single action of one body upon another, to put the latter, if at rest, in motion; or, if it be moving, to increase, retard, or alter the direction of its motion. The point against which the impelling body acts is called the point of impact.

IMPALPABLE POWDERS. Powders so finely levigated, that the particles of which they are formed cannot be distinguished by the senses, more especially that of feeling. Fine pigments. prepared by a flat stone and muller, are reduced to this state.

IMPENETRABILITY is commonly understood to imply that quality of a body by which it cannot be pierced; but in Physics the term has a different, or more refined signification. It is therein defined to be that property of a body by which it prevents any other body from occupying the space in which the former is. Two particles of matter cannot exist at the same time in the same place, for as long as one retains its place, it must necessarily exclude the other. Indeed, were the case otherwise, each body might be successively absorbed into the substance of another, till the whole frame of the universe, collapsing to a point, were lost in the vortex of annihilation. The fact of the impenetrability of even water is easily demonstrated. If a solid body be plunged into a vessel filled with water, a portion of the water will overflow exactly equal to the bulk of the solid body immersed, which shows that it is only a change of places of the substances.

IMPULSE, in Mechanics, the single or momentary action or force by which

a body is impelled by another body striking it, and is distinguished from continued force, such as pulling, pushing, or pressure. Mr. Adams, in his *Lectures on Natural and Experimental Philosophy*, justly observes, "We are forced, by the evidence of every phenomenon in nature, by every experiment in philosophy, to conclude that impulse is the only material cause of motion. All the properties of matter are such as fit them to act, and to be acted upon, in a mechanical way. They are all such as can be adapted to the known principles of mechanism among artists. We are therefore bound by every rule of sound reasoning, to consider it as the cause of all the motion, and continuance of motion, in the material universe. It is the one certain and only universally known cause; for neither the properties of matter, nor experiment, nor observation, afford any other."

INCENSE. See FRANKINCENSE.

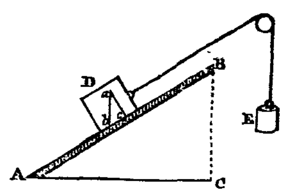
INCH. The twelfth part of a foot; it contains three barley-corns, or twelve lines.

INCIDENCE, or LINE of INCIDENCE, in Mechanics, is the direction in which one body presses or strikes upon another.

INCINERATION. The combustion of vegetable or animal substances, for the purpose of obtaining their ashes or fixed residue.

INCLINATION, in Geometry and Mechanics, the mutual tendency of two lines, planes, or bodies, to each other, making, at the point where they meet, an angle, called the angle of inclination. Thus, the inclination of one line to another, is the acute angle which those lines make where they meet.

INCLINED PLANE. One of the mechanic powers or simple machines by which weights may be elevated with great facility. If a heavy body be suspended freely in space, or against a vertical plane, it is manifest that a weight equal to itself must be employed to sustain it. If, on the other hand, it rest on a horizontal plane, the whole weight is sustained by the plane. But if the body rest on a plane at all inclined to the horizon, a part only of the weight is sustained by the plane. Let A B be a plane inclined to the horizon; D, a body supported on the plane by means of the weight or power E; if the experiment be made by carrying a cord over a fixed pulley, as in the diagram, it will be seen that while the cord continues parallel to the plane, the power E will bear to the weight D the same proportion as B C to B A; that is, as the height of the plane to its length. If the length of A B be six feet, and



the height one foot, a power of one pound will balance six pounds on the plane; if the height be two feet, one pound will balance three, and so on. To ascertain the power obtained by this contrivance we must therefore divide the length of the plane by the height. If the power act parallel to the base, the power is to the weight as the height is to the length of the base. When the power acts parallel to the plane, the power, weight, and pressure on the plane will be proportional to the three lines B C, B A, and A C. For if the weight be represented by *a b*, by the resolution of forces this may be decomposed into *a c*, *c b*, one perpendicular and the other parallel to the plane. Now it is clear that the one which acts perpendicularly on the plane will exert an equivalent pressure, while the part that is parallel to the plane must be sustained by the power. Hence the power, weight, and pressure, are proportional to the sides of the small triangle *a b c*, which is similar to the large one A B C. If the end of the cord be raised above the parallel direction, the pressure on the plane will be diminished, but if it be depressed below the parallel direction, the pressure will be increased, but in both cases a greater power will be required to move the body up the plane. It is, we apprehend, needless to state examples of the application of this method of increasing our power, as its use in assisting to raise bodies to small elevations must be abundantly obvious.

INDELIBLE. Something that cannot be cancelled or effaced, as indelible ink. See ANACARDIUM and INK.

INDEX, in Mechanism, is a light rod, similar to the hand of a clock employed to point out the degrees marked upon a divided scale.

INDIGO. A blue colouring matter, extracted from the leaves and stalks of the *indigofera tincteria,* or *anil* plant. The ancients were acquainted with this dye under the name of Indicum. It is found both in the East and West Indies, is spontaneous in China and Cochin China, and is cultivated all over those vast empires. The seed is sown in little furrows two or three inches deep, and about twelve inches distance from each other. Though it may be sown at all seasons, the moisture of the spring causes the plant to shoot up in three or four days, and it is at maturity at the end of two months. When gathered it is thrown into a large cistern, called the steeping vat, containing sufficient water just to cover the vegetable. The matter begins to ferment, sooner or later, according to the warmth of the weather, and the maturity of the plant, generally occupying from six to twenty hours. When the liquor is in a proper state of fermentation (which is known by its heat, its thickening, an abundant froth that it throws up, and its blue colour, inclining to violet), it is let out by cocks in the bottom, into another vat placed for that purpose. In this second vat, called the beating vat, the liquor is strongly and incessantly beaten with a kind of buckets full of holes, fastened to poles. This part of the process requires the greatest precaution. If the beating is ceased too soon, a part of the colouring matter remains dissolved in the liquor; if continued a little too long, a part of that which is separated is dissolved afresh. The exact time for discontinuing the process is determined by taking up some of the liquor occasionally in a little cup, and observing whether the blue fecula is disposed to separate and subside. The whole being now suffered to rest till the blue matter has settled, the clear water is let off by cocks in the sides, at different heights, and the blue matter at the bottom is discharged by another cock into a third vat, where it is suffered to settle for some time longer, then conveyed, in a half fluid state, into bags of cloth, to strain off more of its moisture; and, lastly, exposed to the air in the shade, in shallow wooden boxes, till it is thoroughly dry.

INERTIA OF MATTER. The name given to a passive principle, by which bodies persist in a state of motion, or rest, receive motion in proportion to the force impressing them, and resist as much as they are resisted. See MECHANICS.

INFLAMMABILITY. That property in certain bodies which disposes them to kindle or take fire readily.

INFUSION, is the operation of macerating or steeping any substance in water or other fluid, hot or cold (but without boiling), so as to extract its soluble parts. The liquid thus impregnated is called an infusion.

INGOT, is a term applied to small bars of gold, silver, copper, and other metals, of a wedge-like shape in their transverse section. The metals are run into this form for portability, the convenience of trade, and their easy application in the arts.

INHALER. The name given to an apparatus having a breathing-pipe, by which a patient inhales steam or other vapours, and sometimes particular gases or airs, presumed to be beneficial in catarrhs, affections of the lungs, &c.

INJECTION. The operation of forcibly throwing any liquid or aeriform fluid by means of a pump, syringe, or other suitable mechanism, into a vessel. Thus, cold water is injected into the condenser of a steam-engine to effect a vacuum.

INKS, are fluid compositions designed for writing, drawing, and printing. As there are a great variety of sorts, we shall treat them consecutively, according to the following arrangement of the subject.

For Writing. 1. On black writing inks generally. 2. On common black writing ink. 3. On best, or Japan ink. 4. Copying ink. 5. Indelible, or indestructible ink. 6. Red ink. 7. Indestructible red ink. 8. Blue ink. 9. Yellow ink. 10. Green, and other coloured inks. 11. Cloth-marking ink. 12. Sympathetic, invisible, or secret inks. 13. Lithographic ink.

For Drawing. 14. Indian, and imitation Indian ink. 15. Lithographic ink, for drawing on stone or paper.

For Printing. 16. Letter-press printing ink. 17. Red, and other coloured ditto. 18. Copper-plate printing ink. 19. Lithographic printing ink.

For removing stains of ink, 20.

1. *Black Writing Inks generally.*—When any vegetable matter, containing the gallic acid, is infused with a solution of iron in water, the gallic acid unites with the iron, and a black liquor results, from which the colour, in the form of an impalpable powder, is gradually precipitated. To prevent the latter effect, it becomes necessary to render the liquor viscid, or of greater specific gravity; and this is best effected by the addition of a gum which is perfectly soluble in water, as this gum, besides keeping the black feculæ suspended in the liquor, serves also to prevent the ink from sinking or spreading on the paper, and likewise to defend it, in the manner of a varnish, from the action of the air. Ink may therefore be regarded as merely a gallate of iron, combined with a little mucilage. It follows, from this view of the matter, that the same, or very nearly the same, kind of black liquid may be produced from a great variety of substances, and, therefore, to make

2. *Common Black Writing Ink.*—It becomes the business of the manufacturer to select such materials as will produce the required quality at the least cost to himself. It is commonly supposed that nut-galls are employed on a large scale for this purpose, but the low price at which common ink is sometimes sold per gallon, renders this improbable; and that such an expensive material (however good) is not necessary, the reader has only to consider that the dyer makes a variety of good blacks without it. Of all known vegetable matters, sumach approaches nearest to galls, and forms a very cheap substitute; combined with the sulphate of iron (green copperas) it makes a very rich black ink, but it requires some peculiar management to prevent its becoming thick. Logwood, from the great affinity of its colouring matter to the oxide of iron, renders it a most desirable substitute for galls. It is well known to be partially used with galls in making ink; but very good common ink may be made from it without any other astringent matter. Valonia, the barks of the oak, chestnut, and many other trees, may be very advantageously applied as useful substitutes for galls in making common ink, and are well deserving of the attention of the manufacturer who may not be acquainted with their properties. A good common ink is made in the following manner: Take 8 ounces of Aleppo galls, in coarse powder, and 8 ounces of logwood, in thin chips; boil these in six quarts of soft water for an hour, and supply the waste from evaporation by the addition of fresh water; strain the decoction through a hair sieve, and then add 5 ounces of sulphate of iron, and 3 ounces of gum Senegal, of ordinary quality. Stir the mixture until the latter is dissolved, then let it subside for twenty-four hours, after which, decant the ink, and preserve it in bottles of glass or stone ware for use. This recipe, it is evident from the preceding remarks, may be considerably varied without material prejudice to the quality of the article; but it should be borne in mind that galls possess more intrinsic value (without reference to their prime cost) than their substitutes, as a given weight of them yields a greater quantity of black precipitate than any of the others; the current price, as well as the quality of the galls, will therefore have to be duly estimated, and in apportioning the substitute a greater quantity must be used.

3. *Best, or Japan Ink.*—M. Ribaucourt, who has paid particular attention to the process of making black ink, has drawn the following inferences from his experiments. That logwood, from its disposition to unite with the solutions of iron, is a valuable ingredient in the making of ink, rendering it not only of a very dark colour, but less capable of change from the action of acids or of the air. That sulphate of copper, in a certain proportion, gives depth and firmness to the colour of the ink. That gum has all the advantages we have before named. That sugar (although it has some bad qualities) is of use in giving a degree of fluidity to the ink, which permits the dose of gum to be enlarged beyond what the ink would bear without it. That water is the best solvent. From these considerations M. Ribaucourt has given the following directions for the composition of good ink, namely, 8 ounces Aleppo galls, 4 ounces logwood, 4 ounces sulphate of iron, 3 ounces gum arabic, 1 ounce sulphate of copper,

and 1 ounce of sugar candy The galls and logwood to be boiled in 12 lbs of water, till reduced to 6 lbs. and after straining, the other ingredients are to be added. This ink flows from the pen of a jet black, and from the gum being in greater proportion to the liquid than in the previous recipe, the writing dries with a gloss upon it; hence it has been called Japan ink. If it is desired to give it more gloss, the gum may be increased. to which some more sugar must be added to give it equal fluidity; but an excess in the latter ingredient renders papers written upon with it liable to stick together, upon contracting the least dampness.

M. Desormeaux, jun. an ink manufacturer of Spitalfields, gave an excellent recipe for making ink some time since in the *Philosophical Magazine;* but as his process does not differ essentially from those we have given, and as his observations are confirmatory, as far as they extend, of our own, we shall only notice the points of difference in his communication. He directs the sulphate of iron to be calcined to a whiteness, and employs coarse brown sugar instead of sugar-candy, the acetate of copper instead of the sulphate, and only in one-fourth the quantity; and recommends the ink to be agitated twice a day for a fortnight before it is poured from the dregs and corked up for use. These variations appear to be judicious and deserving of imitation.

Dr. Lewis and others have recommended vinegar as the menstruum in preference to water; on which, as well as the sulphate of copper of Mr. Ribaucourt, Dr. Ure acutely observes, "I have found an inconvenience in the use of either, which, though it does not relate to the goodness of the ink, is sufficiently great, in their practical exhibition, to forbid their use. The acid of the vinegar acts so strongly upon the pen, that it very frequently requires mending; and the sulphate of copper has a still more unpleasant effect upon the pen-knife. It seldom happens that when a pen requires mending, that the ink is wiped very perfectly from it; and often, when the nib is only to be taken off, it is done without wiping at all. Whenever this is the case, the ink immediately deposits a film of copper upon the knife, and by superior electric attraction of the sulphuric acid, a correspondent portion of the edge of the knife is dissolved, and is by this means rendered incapable of cutting until it has been again set upon the hone.

4. *Copying Ink,*—for transferring writings to thin unsized paper is prepared by the simple addition of a little sugar to common writing ink. The powerful affinity of water to sugar, causes the damp paper to immediately absord the ink by the powerful aid of the copying-machine. See Copying Press.

5. *Indelible Ink.*—It is well known that common writing ink may be easily obliterated by the application of oxymuriatic acid, or aqueous chlorine; it therefore becomes an important object to employ those substances which shall be indestructible by the application of any process that will not at the same time destroy the material upon which it shall be used. For this purpose Mr. Close has recommended twenty-five grains of copal in powder, dissolved in two hundred grains of oil of lavender, by the assistance of a gentle heat, and then mixed with two and a half grains of lamp-black, and half a grain of indigo. A little oil of lavender, or of turpentine, may be added if the ink be too thick. Mr. Sheldrake suggests that a mixture of genuine asphaltum, dissolved in oil of turpentine, amber varnish, and lamp-black, would be superior to the foregoing. For many common purposes the introduction of a little lamp-black into the composition of common ink will answer sufficiently. In the *Journal of the Royal Institution* the following process of making an indelible ink has been recommended:—Let a saturated solution of indigo and madder in boiling water be made in such proportion as to give a purple tint; add to it from one-sixth to one-eighth of its weight of sulphuric acid, according to the thickness and strength of the paper to be used. This makes an ink which flows pretty freely from the pen; and when writing which has been executed with it is exposed to a considerable but gradual heat from the fire, it becomes completely black, the letters being thoroughly burnt in, and charred by the action of the sulphuric acid. If the acid has not been used in sufficient quantity to destroy the texture of the paper, and reduce it to the state of tinder, the

colour may be discharged by the oxymuriatic and oxalic acids, and their compounds, though not without great difficulty. When the full proportion of acid has been employed, a little crumpling and rubbing of the paper reduces the carbonaceous matter to powder; but by putting a black ground behind them they may be preserved; and thus a species of indelible writing ink is procured, (for the letters are in a manner stamped out of the paper) which might be useful for some purposes, perhaps for the signature of bank notes. (See the inks for marking linen.) When writing with common ink has been effaced by means of aqueous chlorine, the vapour of sulphuret of ammonia, or immersion in water impregnated with this sulphuret, will render it again legible. Or if the paper that contained the writing be put into a weak solution of prussiate of potash, and when it is thoroughly wet, a little suphuric acid be added to the liquor, so as to render it slightly acidulous, the same purpose will be answered.

6. *Red Inks.*—Steep one pound of powdered Brazil wood, and one ounce of powdered cochineal, in two gallons of vinegar. Let them macerate for twelve hours. Then put the whole on to a slow fire, with four ounces of alum, and one ounce of lump-sugar, in a pewter vessel, until a good red colour is obtained. When the ink is settled it may be decanted, pouring it through a piece of cloth into bottles, and preserved for use. Cochineal is a very expensive article, and although it is usual to recommend its introduction into red ink, on account of the richness of its colouring matter, we know from experience that it is by no means a necessary ingredient, and that a beautiful and very permanent red may be obtained without it. We have before us a recipe, written fifteen years ago in the identical red ink it is descriptive of the process of making; the colour is extremely beautiful, nor in the least deteriorated by the lapse of time. The process differs only from the above recipe in using no cochineal, but it contained as much alum as the liquid would dissolve in its cold state; the Brazil wood was macerated during a night, and was very gently boiled in an *unglazed* earthen pot on the next day, for half an hour; afterwards one pound of Senegal gum, and a quarter of a pound of lump-sugar, were added. With so large a proportion of mucilage as just mentioned, and so much alum, it is probable that vinegar may be dispensed with, and that water alone, which is a good menstruum for the colouring matter of Brazil wood, will answer very well, and materially cheapen the ink. Care should be taken to discontinue the boiling after the full bright red is obtained, as by continuing it the colour darkens; also, that copper or iron vessels should not be used, unless they are perfectly coated with tin in every part. A solution of tin heightens the red colour, and tends to restore it, if it has acquired a purple tint.

7. *Indestructible Red Ink* may be made by dissolving one ounce of copal in seven ounces of oil of lavender, and adding thereto three ounces and a half of pure vermilion. If found too thick for the pen, add a little more oil of lavender.

8. *Blue Ink.*—Take sulphate of indigo (indigo dissolved in sulphuric acid, it may be had of the dyers), and dilute it with water till the desired tint is obtained. It is with this sulphate, very largely diluted, that the faint blue lines of ledgers and other books are ruled. If the ink were used strong, it would be necessary to add chalk to it, to neutralize the acid.

9. *Yellow Ink.*—Half a pound of French berries, boiled with a little alum in a quart of water, or vinegar and water.

10. *Green and other coloured Inks.*—A mixture of the above blue and yellow inks will make a *green;* a mixture of the red and yellow will make an *orange;* of the blue and red, a *purple;* of the black and yellow, a *brown.* Inks of all colours may, however, be very readily obtained by rubbing down with water any of the water-colours prepared in cakes, for artists; or by using a strong decoction of any of the ingredients used in dyeing, with a little alum and gum.

11. *Marking Linen.*—Mr. Haussman has given some compositions for marking pieces of cotton and linen, previous to their being bleached, which are capable of resisting every operation in the processes both of bleaching and dyeing, and consequently might be employed in marking linen for domestic purposes. One

of these consists of asphaltum, dissolved in about four parts of oil of turpentine, and with this is to be mixed lamp-black or black-lead in fine powder, so as to make an ink of a proper consistence for printing with types. Another,—the blackish sulphate left after expelling oxygen gas from oxide of manganese with a moderate heat; being dissolved and filtered, the dark grey pasty oxide left on the filter is to be mixed with a very little of a solution of gum tragacanth, and the cloth marked with this is to be dipped in a solution of potash or soda, mild or caustic, in about ten parts of water. The anacardium, or cashew nut, it is well known, yields an inflammable caustic liquor, which alone forms a very useful marking ink, as any thing written on linen or cotton with it is of a brown colour, which gradually grows blacker, and is very durable. The ordinary marking ink sold in our shops is made in the following manner:—Take lunar caustic (nitrate of silver), 5 scruples; gum arabic, 5 scruples; sap-green, 1 scruple; water, 1 ounce; put these together in a small bottle, and the ink is formed. In using it, the linen is first wetted with the following mordant;—1 ounce of soda to 2 ounces of water. The marking ink should not be used until the mordant has dried upon the linen.

12. *Sympathetic, Invisible, or Secret Inks,* are such as do not appear after they are written with, but which may be made visible at pleasure, by certain means used for that purpose. They are of considerable antiquity; for it appears that Ovid recommends the maidens of his days, who wished to correspond secretly with their lovers, to write with fresh milk, which when dried might be made visible by rubbing over it ashes or rust. Pliny, who was better informed than Ovid in such arts, though probably less inclined to practise them, recommended the milky juice of certain plants for the purpose; but the use of such things is superseded by the discoveries of modern chemists, who have introduced to our notice a great variety of secret inks, the best of which we find selected in the *Oxford Cyclopædia*; they are as follow:—Dissolve some sugar of lead in water, and write with the solution. When dry, no writing will be visible. When you want to make it appear, wet the paper with a solution of alkaline sulphuret (liver of sulphur,) and the letters will immediately appear of a brown colour. Even exposing the writing to the vapours of these solutions will render it apparent.—Write with a solution of gold in aqua-regia, and let the paper dry gently in the shade: nothing will appear; but draw a sponge over it, wetted with a solution of tin in aqua-regia, the writing will immediately appear of a purple colour.—Write with an infusion of galls, and when you wish the writing to appear, dip it into a solution of green vitriol; the letters will appear black.—Write with diluted sulphuric acid, and nothing will be visible. To render it so, hold it to the fire, and the letters will instantly appear black.—Juice of lemons or onions, a solution of sal ammoniac, green vitriol, &c. will answer the same purpose, though not so easily, nor with so little heat.

Green Sympathetic Ink. — Dissolve cobalt in nitro-muriatic acid, and write with the solution. The letters will be invisible till held to the fire, when they will appear green, and will disappear completely again when removed into the cold. In this manner they may be made to appear and disappear at pleasure. A very pleasant experiment of this kind is to make a drawing representing a winter scene, in which the trees appear void of leaves, and to put the leaves on with this sympathetic ink; then upon holding the drawing near to the fire, the leaves will begin to appear in all the verdure of spring, and will very much surprise those who are not in the secret.

Blue Sympathetic Ink. — Dissolve cobalt in nitric acid; precipitate the cobalt by potass; dissolve this precipitated oxide of cobalt in acetic acid, and add to the solution one-eighth of common salt. This will form a sympathetic ink, that, when cold, will be invisible, but will appear blue by heat.

13. *Lithographic Ink.*—As the art of lithography is treated of generally under its initial letter in this work, we shall in this place simply notice the autographic ink, suitable for transferring to stone the writings or drawings which have been executed on paper prepared for the purpose. This ink ought to be mellow, and somewhat thicker than that used for drawing or writing imme-

diately on stone; so that when it is dry on the paper, it may be still sufficiently viscous to cause it to adhere to the stone by simple pressure. The following is the mode of preparing it: dry soap, 100 drachms; white wax, pure, 100 ditto; mutton suet, 30; shellac, 50; mastic 50; and lamp-black, (fine, from the combustion of resin,) 30 to 35 drachms. These are to be melted over a brisk fire in a metal pot over a chafing dish; first melt the soap and the suet, then add the shellac very gradually; next the soda, a little at a time, and after this the mastic, taking care to stir it from time to time with a wooden spatula; lastly the lamp-black, stirring it all the time. When these materials are well incorporated, they are poured on a plate of cast iron, made warm, and oiled, in order that the composition may be easily detached from it. Ledges of wood are put on the plate to keep the thickness of the composition uniform, which when congealed, but still warm, is cut into sticks, like Indian ink.

14. *Indian Ink.*—The genuine article, which is used by the Chinese for writing with a brush, as well as for painting upon their soft, flexible paper, is ascertained by experiment and information to consist of lamp-black and size, animal glue, with the addition of perfumes or of other substances not essential to its quality as an ink. The fine soot from the flame of a lamp or candle, received by holding a plate over it, mixed with clean size from shreds of parchment of sheep and goat skins, will make an ink equal to that imported. We have been in the habit of using, during many years, both the genuine and the imitation Indian ink indifferently, without being able to discover that either merits a preference.

15. *Lithographic Drawing Ink.*—This composition is the same as the ink used for writing upon stone and lithographic transfer paper, already described; the artist rubbing it down usually upon a slab, as Indian ink, for his use.

16. *Letter-press Printing Ink* is a very smooth and jet black oil paint. The consistence and tenacity of the oil in this composition are greatly increased, and its greasiness diminished, by means of fire. Linseed oil, or nut oil, is made choice of for this use. The nut oil is supposed to be the best, and is accordingly preferred for the black ink, though the darker colour it acquires from the fire renders it less fit for the red. It is said, that the other expressed oils cannot be sufficiently freed from their unctuous quality. Ten or twelve gallons are set over the fire in an iron pot, capable of holding at least half as much more; for the oil swells up greatly, and its boiling over into the fire would be very dangerous. When it boils, it is kept stirring with an iron ladle; and if it do not of itself take fire, it is kindled with a piece of flaming paper or wood. It is found that mere boiling, without setting it on fire, does not give it a sufficiency of the drying quality. The oil is suffered to burn for half an hour or more, and is then extinguished by covering the vessel close, and excluding the air. The boiling is continued with a gentle heat, till the oil has attained the proper consistency, in which state it is called varnish. It is necessary to have two kinds of this varnish, a thicker and a thinner, (from the greater or less boiling it has received,) which are occasionally mixed together, to suit different purposes; for that which answers well in hot weather, becomes too thick in cold, and large characters or type do not require such stiff ink as the small. The thickest varnish, when cold, may be drawn into threads, like glue; and the workmen taking out small quantities, from time to time, judge of the proper degree of boiling required, by testing its tenacity in that manner. The oil loses by the boiling about one-eighth of its weight. The varnish readily mingles with fresh oil, and it will unite with mucilages, into a mass that is afterwards diffusible in water. About one-seventh part, by weight, of lamp-black is added to the varnish, to give it the depth of colour. Boiled with caustic alkali, a soapy compound is formed, and printers availing themselves of this fact, are in the habit of cleaning their types by soap-makers' lees and a brush. It is said that when very new oil is used in making ink, it does not readily dry without the addition of litharge, or the oil of turpentine, and these additions (which are not necessary in old oil) cause it to stick very hard to, and clog up the types.

17. *Red and other coloured Printing Inks,* are made from linseed oil, boiled

into a varnish, as described in the black ink, with the addition of some dry pigment of the required colour, which is ground up with the varnish, with a stone and muller in the manner of oil paint. Thus, for preparing the bright red printing ink, vermilion is ground up with the varnish, in such quantity as will give the required depth of tint. In like manner for blues, yellows, oranges, greens, &c. the Prussian blue, indigo, orpiment, chrome, red and orange lead, verdigris, and in general the pigments used by house painters, are similarly combined with the varnish.

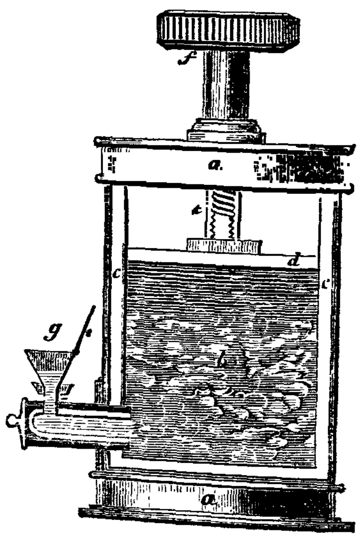
18. *Copperplate Printing Ink* is of a somewhat similar kind to that used for type printing, but the oil is less boiled, and the varnish is in consequence much more fluid; and instead of lamp-black, they either use the black imported from Frankfort, (which is said to be the charcoal of vine twigs, prepared in a peculiar manner,) or when this cannot be procured, or is too costly, the finest ivory black they can obtain.

19. *Lithographic Printing Ink* differs from that used in typography, only in being a much thicker varnish; and the lamp-black which is used as the colouring matter is not mixed with it in the mass, but small portions of the varnish are taken from time to time, as it is required, and the lamp-black then only ground up with it for immediate or very early use. See LITHOGRAPHY.

20. *Removing Stains of Ink.* The stains of ink on cloth, paper, or wood, may be removed by almost all acids; but those acids are to be preferred which are least likely to injure the texture of the stained substance. The muriatic acid, diluted with five or six times its weight of water, may be applied to the spot, and after a minute or two may be washed off, repeating the application as often as may be found necessary. But the vegetable acids are attended with less risk, and are equally effectual. A solution of the oxalic, citric (acid of lemons), or tartaric acids in water, may be applied to the most delicate fabrics, without any danger of injuring them; and the same solutions will discharge writing, but not printing ink. Hence they may be employed in cleaning books that have been defaced by writing on the margin, without impairing the text. Lemon-juice, and the juice of sorrel, will also remove ink stains, but not so easily as the concrete acid of lemons, or citric acid.

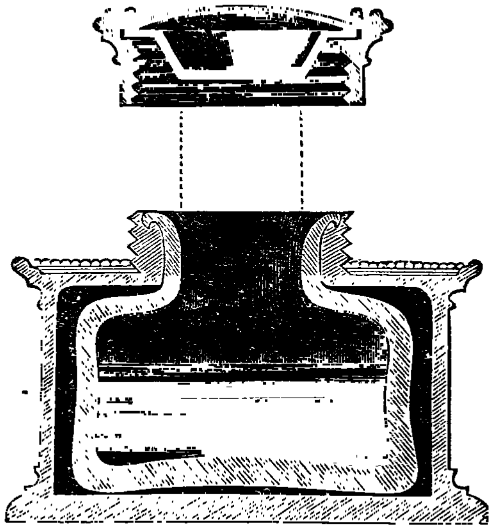
INKSTANDS. Utensils for holding ink for the convenience of dipping a pen into them. They were formerly chiefly made of horn, but now generally of glass or metal. It is not our intention to describe the ordinary kinds, that are familiar to every eye, but only the recent elegant improvements which have been made upon them.

Edwards's Patent Inkstand is one of great convenience and stability, and not very liable to get out of order. It is represented in the subjoined engraving, which affords a sectional view of the interior. *a a* shows the top and bottom of an external cylindrical casing of bronze, *b* is the ink imbibed by a quantity of loose hair or wool, contained in a cylindrical glass cup *c c*, of considerable thickness, the upper part of which is closed by a glass piston *d*, accurately ground to fit the cylinder, and so as to permit it to move easily up and down. On the upper surface of the glass piston, a hollow screw *e* with a disc of metal at the end, is made to operate by pressure downwards, when the top piece *f* is turned by the finger and thumb; the latter turns the solid screw, and causes the hollow screw to advance or recede with a sliding motion, so as to press



uniformly upon the piston without the friction of turning against its surface. At the lower part of the reservoir, an aperture is made, into which a tube is fixed that conducts the ink to a little pen-supplying cup *g*, when the wool is compressed by a turn of the screw, forcing down the piston. The little cup, previously empty, is thus instantly supplied with fresh ink, with no more trouble than taking up a pen; and should a little more ink be forced into the cup than is necessary, by carelessly turning the screw too far, it runs over, and is caught in the little saucer shown below. When the inkstand is not in requisition, a half turn of the screw the reverse way causes the ink to flow back again, as the wool being thereby relieved of the pressure, re-absorbs the fluid. The ink being thus returned into the reservoir, none can be spilled, even if upset; it is preserved from the contact of the air, consequently from drying up, as well as from dust, and it may be instan[illegible] henever required. These are decided advantages, which [illegible] it for the use of persons travelling.

Patent Caoutchouc Inkstand.—Mr. Doughty, the ingenious manufacturer of pens with ruby and rhodium nibs, having discovered the injury that those pens received from being incautiously struck against the glass of common inkstands, contrived to manufacture an interior bottle of Indian rubber, of nearly the form of the external ornamental case, as shown in the annexed section of one of his

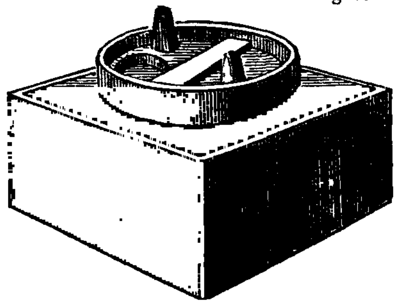


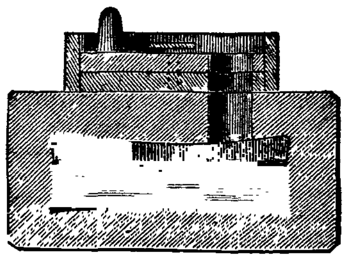
elegant inkstands. The stopper is of a conical form, and is so fixed in the screwed head or cap as to have a little lateral play therein, which admits of its adapting itself exactly to the conical neck of the inkstand, and when screwed down, prevents the possibility of leaking; and that the ink may not corrode the metal stopper, the latter is coated with gold or platinum.

Horsley and Cooper's Patent Inkstand.—The peculiarity in this invention consists in the forming of convenient and perfectly air-tight stoppers, in a substance not liable to corrode. It is effected by bringing into contact two circular discs of glass, the flat surfaces of which being ground to true planes, are opposed to each other and united by a central pivot, rivetted to a bar of metal fixed above them, across the mouth of the vessel. Each plate has an aperture of proper dimensions for dipping the pen, and the upper plate is

provided with two projecting studs, at equal distances from the central pivots. The thumb and fore finger being applied to these two studs, the upper disc is easily turned either to the right or left; one way brings the apertures opposite to each other, which *opens* the inkstand, and being moved the other way, the unperforated part of the upper disc is slided over the stationary aperture of the lower, and perfectly closes it. The rubbing surfaces are slightly oiled, which renders the motion smooth and easy, and the sealing perfect. *Fig* 1. affords a perspective view of an inkstand of this kind, made of very thick cut glass; the discs or stoppers of which are surrounded by a metallic ring, and kept down in their places by an horizontal metallic bar, into which the pivot of the discs is fitted. In this figure it will be perceived that the inkstand is shut, the aperture in the upper plate being over the unperforated part of the lower. On turning the studs a quarter round, they are stopped by striking against the cross bar, when the two holes coincide, (as shown in the annexed sections), by which the inkstand is opened. Underneath the bar (which is shown by a transverse section) a steel spring is fixed, which keeps the discs in close yet easy contact. The advantage of this contrivance consists in the facility and expedition with which the inkstand may be opened and closed air tight, the simplicity of the construction, and the incorruptibility of the materials.

Fig. 1.





INSOLATION. A method of preparing certain fruits, drugs, &c. by exposing them to the heat of the sun's rays, either to dry, to maturate, or to render them acid; as is done in figs, raisins, vinegar, and many other products.

INTAGLIOS. Precious stones, on which are engraved the heads of eminent men, such as are usually set in seals, rings, &c.

INTEGER, in Arithmetic, signifies a whole number, in contradistinction to a fraction.

INTEGRAL, in Philosophy, is an appellation given to parts of bodies which are of a similar nature to the whole.

INTEGRAL CALCULUS is the reverse of the differential calculus, and is the finding of the integral from a given differential, and corresponds with the inverse method of fluxions.

INTERMEDIATES. A term made use of in Chemistry in relation to affinity; thus, oil has no affinity to water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the intermedium which causes the union.

INTRADOS. The internal curve of the arch of a bridge.

INVERSE PROPORTION, or Inverse Ratio, in Philosophy, is that in which more requires less, or less requires more. Thus in the case of light and heat flowing from a luminous body, the light and heat are less at a greater distance and greater at a less distance.

IODINE and IODIC ACID. Iodine is a peculiar and compounded principle; it was discovered in Paris in 1811 by M. Courtois, a saltpetre manufacturer, who observed a rapid corrosion of his vessels in his processes for obtaining soda from the ashes of sea weeds; and in searching for the cause of the corrosion, he made the discovery of this important substance. It is from sea weeds

alone that iodine can be obtained; it has not yet been decomposed; it is of a greyish-black colour, and metallic lustre; soft and friable to the touch; taste acrid, and a deadly poison. It gives a brown stain to the skin, which speedily vanishes by evaporation. The specific gravity of iodine at 62°, is 4.948: it dissolves in 7,000 parts of water, and the solution is of an orange yellow colour, and in small quantities tinges raw starch of a purple hue. Iodine is incombustible; but with azote it forms a detonating compound, and in combining with several bodies it produces the phenomenon of combustion. The oxide of sodium, and the subcarbonate of soda are completely decomposed by it. It forms with sulphur a compound of greyish black, radiated like sulphuret of antimony. Iodine and phosphorus combine with great rapidity at common temperatures, and produce heat without light. Hydrogen, whether dry or moist, does not seem to have any action on iodine at the ordinary temperature; but if we expose a mixture of hydrogen and iodine to a red heat in a tube, they unite together, and hydriodic acid is produced, which gives a reddish brown colour to water. Charcoal has no action upon iodine. Several of the metals, as zinc, iron, tin, mercury, attack it readily, even at a low temperature, provided they be in a divided state. Iron is acted upon by iodine in the same way as zinc, and a brown iodine results. Antimony presents with iodine the same phenomena as tin. The iodines of lead, copper, bismuth, silver, and mercury, are insoluble in water; this is at least the case with the above-mentioned metals. There are two iodines of mercury; the one yellow, the other red; both are fusible and volatile. When iodine and oxides act upon each other in contact with water, its hydrogen unites with iodine to form hydriodic acid; while its oxygen, on the other hand, produces with iodine *iodic acid*. Iodine of mercury has been proposed for a pigment. Iodine has been most successfully applied medicinally for reducing the goitre and glandular swellings. See *Ure's Dictionary*.

IRIDIUM. A new metal, to which that name was given by its discoverer, Mr. Tennant, from the striking variety of colours it affords whilst dissolving in muriatic acid. On examining the black powder left after dissolving platina, Mr. Tennant found it to contain two distinct metals never before noticed, which he named iridium and osmium. Lead unites with iridium easily, but separates by cupellation, leaving the iridium in the cupel as a coarse black powder. Copper forms with it a very malleable alloy, which, after cupellation, with the addition of lead, leaves a small proportion of the iridium, but much less than in the preceding instance. Silver forms with it a perfectly malleable compound, the surface of which is tarnished merely by cupellation; yet the iridium appears to be diffused through it in fine powder only. Gold remains malleable and little altered in colour, though alloyed with a considerable proportion; nor is it separable either by cupellation or quartation. If the gold or silver be dissolved, the iridium is left as a black powder.

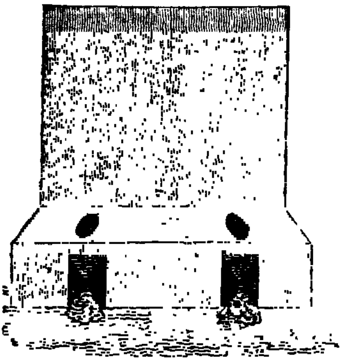
IRIS METAL ORNAMENTS. A patent was taken out a few years ago by Mr. Barton, of the Mint, for a very ingenious method of ornamenting steel and other metals with the prismatic colours. It is effected by engraving with an engine lines on the surface of the metals of extreme minuteness, so as to divide a lineal inch into from 2000 to 10,000 equal parts. Mr. Barton has sometimes proved the correctness and stability of his engine, when drawing lines 2000 in an inch, by leaving out one line intentionally, then taking the machine to pieces; afterwards, on putting it together again, he has introduced the omitted line in its place, without causing it to be distinguishable from the rest.

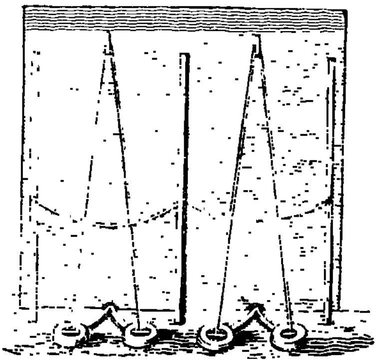
In applying the principle of striated colours to ornament steel, the effect or pattern is produced upon the polished surface by the point of a diamond; so that either the whole, or a part of the surface, is covered with lines or grooves, whose distance may vary from the one-thousandth to the ten-thousandth of an inch. When these lines are most distant, the prismatic images of any luminous body, seen by reflection from the polished surface, are nearest one another, and the common colourless image; and when the lines are least distant, the coloured images are farthest from one another, and the colours are most vivid. In day-light the colours produced by these minute grooves are scarcely distinguished,

unless at the boundary between a dark and a luminous object. In sharp lights, however, and particularly in that of the sun, the colours shine with extraordinary brilliancy, and the play of tints which accompany every luminous image can only be equalled by their matchless exhibition in the reflections of the diamond. Steel dyes are engraved in this manner, from which impressions are afterwards taken for the fabrication of various articles, in which the design of the original is very faithfully transferred.

IRON. A metal of a bluish-white colour, of great hardness and elasticity; very malleable, and exceedingly tenacious and ductile. It is the most abundant, the most important, and the most valuable of all the metals. Although a simple undecompounded substance, it is not naturally found in this state, except in comparatively minute quantities, but is the product of art. Some specimens of native iron, nearly pure, have been found in Siberia and South America; also many iron stones, rich in the metal, supposed to be of volcanic or meteoric origin, have been found in numerous parts of the earth; but all the iron of commerce is obtained by chemical means. Iron is so universally diffused as to form a constituent part of almost all animal, vegetable, and mineral substances. Unlike metals of inferior utility, its ores are not distributed in thin veins, or scattered in minute particles, but are thickly stratified over many thousands of square miles, chiefly in the northern regions of the earth, where nature has been less profuse of her other benefits. The use of this metal is of very great antiquity, though, on account of the difficulty of separating it from its ores, and of working it, probably not so remote as the employment of gold, silver, copper, and other comparatively soft metals, which are in many places found in a pure metallic state. It is stated by some writers, that iron is mentioned by Moses as the material of which knives and swords were fabricated; and that Herodotus mentions the presentation of a saucer, or vase of iron, very curiously inlaid, by Alyattes, king of Lydia, to the Delphic oracle. Later and more erudite writers have, however, maintained that the words of those ancient authors have been most incorrectly translated into our language; and that the working and use of iron was unknown at those periods. At what time the manufacture of iron was first attempted in Britain, cannot be precisely ascertained. Some suppose (for it is in reality only a probable conjecture) that the Phœnicians who wrought the tin mines of Cornwall, introduced into the country men who were skilled in metallic ores, and capable of estimating their value, by applying the minerals to such purposes as their own necessities or the wants of the inhabitants might require. There is, however, much evidence to favour the belief that iron was worked in this country during the time it was in occupation by the Romans; and that during the establishment of the Danes in England, the arts of mining and manufacturing the ores of iron were much improved. It appears that the manufacture was at that period chiefly directed to the fabrication of *malleable* iron, in what were called *foot-blasts*, of a similar nature to those still used in remote uncivilized countries, of which Dr. Davy has furnished us with an example in a Singalese smelting house of the present day. The simplicity and cheapness of construction of this furnace is extremely interesting, as showing what may be effected by very limited means, and that the large capitals and immense laboratories employed by our present iron manufacturers, however necessary they may be to the production of a large quantity of the metal, are by no means essential to the production of a good quality; for it has been generally remarked, that the ruder the method employed in any country for the reduction of iron, the better the quality of the metal is. The observation holds good in Ceylon, and there is obvious reason why it should be correct. Where the art is little advanced, the most tractable ores are selected, and charcoal is the fuel always used, circumstances which are alone sufficient to account for the iron obtained being excellent. Each furnace was, at its mouth, about 1 foot and 4 inches, by 8 inches in diameter; about 3 feet deep, and terminated in the form of a funnel, over a shallow pit inclining outwards. They were made in a bed of clay about 3 feet high, and 3 feet wide, against which a light wall, about 10 feet high, was raised to protect the bellows and operator, who was situated immediately behind. Each bellows

consisted of a circular rim of wood, about 6 inches in diameter, and scarcely 2 inches high, fixed on a clay floor, and covered with moist cow-hide; in the centre of which was a hole to admit air, and to receive a cross stick, to which a cord was attached that was fastened above to an elastic stick. Each pair of bellows was worked by a boy, who rested his back against a rope for the purpose of support, and stepped alternately from the orifice of one bellows on to that of the other, at each step forcing a blast of air into the furnace through a





tube of bamboo. The furnaces were charged with a mixture of iron ore, broken into small pieces, and charcoal. The fires were kept up as strong as possible till the ore was reduced, and the fused metal collected in a cake in the ash-pit.

At the time when foot-blasts were used for separating the metal, the art of casting iron was either altogether unknown, or in a state that it could not be prosecuted with advantage. In the reign of Elizabeth, blast furnaces were of a sufficient size to produce, with ores and the charcoal of wood, from two to three tons of pig-iron per day, or from fifteen to twenty tons per week. It was only, however, in the most favourable situations for obtaining water-power that such great products were obtained, and the greatest proportion of it was converted into bar-iron by means of the refinery fire; but in many of the small works the iron was "matured," that is, made malleable, before it was drawn from the furnace. Wood, however, becoming scarce, or being engrossed by the great manufacturers, induced several enterprising individuals to attempt the substitution of pit coal for making pig-iron. Mr. Simon Sturtevant, 1612, had a patent granted to him, for thirty-one years, for that purpose. By the terms of his patent he was bound to publish the nature and process of his invention, which he did, in a quarto book, entitled *Metallica;* this book, Mr. Gray says, does not contain a particle of useful knowledge, but that it is an extremely curious specimen of the pedantry usual in James's reign. Sturtevant failed in executing his proposed plans, and was obliged, the following year, to render up his letters patent, or monopoly. John Ravenson, Esq. succeeded Sturtevant in 1613, had a patent granted to him, wrote his book, entitled "*A Treatise of Metallica, but not that which was published by Mr. Simon Sturtevant.*" Ravenson states, that at that time an iron work usually required from 1000*l.* to 1500*l.* to set it a-going, but that on his plan a capital of 100*l.* was fully adequate to commence a work. The furnace itself was to cost but 10*l.* except the stones, such furnace being capable of producing a ton of sow iron from each ton of pit coal. This man, however, failed in his attempts to prove the correctness of his statements, and resigned his patent. Several other unfortunate adventurers followed Ravenson in succession, who also obtained patents, failed in their undertakings, and resigned their privileges. It is a singular fact, that although pit coal was known long before this period, and great quantities of it were

exported to Holland and the Low Countries, where it was used in the smith's forge, and in other manufactories that require a strong continued heat; yet in England the prejudice against its use in the manufacture of cast iron was so inveterate, that when it was first proposed and attempted, every obstacle that could be devised was thrown in its way, and none of the adventurers succeeded, until the year 1619, when Dudley had a patent, and manufactured pig-iron in a blast furnace, but produced only three tons in a week. He became, however, the object of jealousy to the other manufacturers, who contrived to get his patent limited from thirty-one to fourteen years, and his devoted works were destroyed by a lawless mob, urged, it is supposed, by his rivals in business. Soon after this, Captain Buck, Major Wildman, and some others, constructed air furnaces in the forest of Dean, in which they placed large clay pots (similar to those used in glass-houses) for containing the requisite preparations of ore and charcoal, the flame of pit coal being employed for heating the furnaces; and it was expected, that by tapping the pots below, the separated material would flow out. But the heat was not sufficiently intense to produce an entire separation of the metal, the pots cracked, and the scheme was abandoned. At this time iron was advancing, in consequence of many of the iron works having stopped for want of fuel. To those manufacturers, therefore, who could still be furnished with a supply of wood, the manufacture was highly profitable, and they obstinately opposed any new attempt by which the price of iron might be diminished. It was not till impelled by necessity, arising from the rapid decline of the annual growth of timber, that pit coal became an object of universal estimation. In this feeling the Hon. Robert Boyle seems to have participated, for in his *Usefulness of Natural Philosophy*, published in 1663, he expresses a desire that some method could be found to make coke without the use of pots employed for that purpose, in order that it might be applied to the smelting of iron ores. Two years after this, Dudley (according to Mr. Gray) wrote his *Metallum Martis*, in which he states, that his father and himself had smelted iron with coke in large quantity, but that Oliver Cromwell, and some favourites of his, wishing, on a renewal of the patent, to become partners, and other political circumstances, had ruined the establishment, which seems never to have been revived; for even so late as the year 1747, Mr. Mason says, in the *Philosophical Transactions*, that several attempts have been made to melt iron ore with pit coal, but he thinks it had not then *succeeded* any where, as no account of its being practised had been published, but that Mr. Ford did, however, then make pig iron, brittle or tough, as he pleased, from iron and coal, both of which were procured on the same spot. The brittle or inferior quality of English bar iron, made from coke at this period, and the great expense of that which was made from charcoal, owing to the increasing scarcity of wood, was most likely the cause of the great decline in the home manufacture of iron which then took place; recourse having been had to Sweden and Russia for a supply, the importation of which on a great scale at this time commenced. The home manufacture was, however, again renewed by the general introduction of the steam engine, which afforded the manufacturer the command of a power he had before no conception of. The small furnaces supplied with air from bellows worked by oxen, horses, or men, were given up; larger furnaces were introduced, and blowing machines, with an increase of the column of air for exciting a more vivid combustion. The steam engine was found particularly beneficial in those situations where there was an abundance of minerals for making iron, but a deficiency of water to supply the power. Experience also soon taught the manufacturer, that the produce of his furnace could be increased by enlarging the diameter of his steam cylinder and rendering the vacuum therein more perfect. It was soon found, that by increasing these effects, a quantity of pig-iron could be produced from the coke of pit coal, which would be attended with an adequate profit. Owing to the small quantity of air necessary to ignite, and preserve the required heat in a charcoal furnace, the manufacturers very cautiously enlarged the dimensions of their blowing apparatus in applying it to coke; consequently much of the advantage resulting from a great blast (which is now extended to about 4000

cubic feet of air per minute) was lost. These difficulties were, however, gradually surmounted, and it appears, that before the year 1760, the coke of pit coal was in general use for blast furnaces. The iron trade assumed new vigour, and made most rapid progress, as will appear from the following statement of the total quantity of iron made in Great Britain between the years 1740 and 1827. Since the latter period, the manufacture and trade has been on the increase, notwithstanding the price has advanced.

In the year	1740,	17,000 tons were made	from	59	furnaces.
„	1788,	68,000 tons	„	121	„
„	1796,	125,000 tons	„	—	„
„	1806,	250,000 tons	„	—	„
„	1820,	400,000 tons	„	—	„
„	1827,	690,000 tons	„	284	„

Of which latter quantity there were produced—

By Staffordshire	216,000	tons from	95	furnaces.
By Shropshire	78,000	„	31	„
By South Wales . . .	272,000	„	90	„
By North Wales . . .	24,000	„	12	„
By Yorkshire	43,000	„	24	„
By Derbyshire	20,500	„	14	„
By Scotland	36,500	„	18	„
Total	690,000	„	284	„

In the foregoing statement, several furnaces in Gloucestershire, Cheshire, and other places are omitted, which will render the produce in round numbers 700,000 tons. About three-tenths of this quantity are of a quality suitable to the foundry, which is all used in Great Britain and Ireland, with the exception of a small quantity exported to France and America. The other seven-tenths are made into bars, rods, sheets, wire, &c., of which a large quantity is exported to all parts of the world. Having thus given a brief historical sketch of the rise and progress of this interesting and useful manufacture, we proceed to lay before our readers a concise account of the process by which iron is obtained from its ores, and brought into a crude or pure state, adapted to the wants of mechanics, or to the various uses to which it is applied.

Making of Coke.—The first operation is the preparation of the coal, to reduce it to the state of coke, which is accomplished either in kilns, or in the open air. The latter plan has been, and is still, the most extensively adopted; we shall therefore describe it the first. An oblong square hearth is prepared, by heating the earth to a firm flat surface, and paddling it over with clay. On this the pieces of coal are piled up, inclining toward one another; and those of the lower strata are set upon their acutest angle, so as to touch the ground with the least surface possible. The piles are usually from 30 to 50 inches high, from 9 to 16 feet broad, and contain from 40 to 100 tons of coal. A number of vents are left, reaching from top to bottom, into which the burning fuel is thrown; and they are then immediately closed with small pieces of coal beaten hard in. Thus the kindled fire is forced to creep along the bottom, and when that of all the vents is united, it rises gradually, and bursts out on every side at once. If the coal contain pyrites, the combustion is allowed to continue a considerable time after the disappearance of the smoke, to extricate the sulphur, part of which will be found in flowers on the surface. If it contain none, the fire is covered up soon after the smoke disappears, beginning at the bottom and proceeding gradually to the top. In 50, 60, or 70 hours, the fire is in general completely covered with ashes of char, formerly made, and in twelve or fourteen days the coke may be removed for use. In this way a ton of ordinary bituminous coal commonly produces from 700 to 1,100 lbs of coke.

Coke and Tar Works.—The annoyance attending this process by the evolution of the immense quantities of smoke from the ignited matter, besides the entire

waste of the volatile products, induced Lord Dundonald, many years since, to carry into effect a plan for preventing the former, and saving the latter. One of these tar works, as they were called, was erected at Mr. Wilkinson's great works at Bradley, another at Tipton, and a third at the Level Colliery and iron works upon Dudley-wood. Being erected in the vicinity of large iron and coal works, the iron masters furnished the tar works with raw coal, and received in return the cokes produced by such coal, the proprietors being compensated by the volatile products, viz. tar, pitch, varnish, and ammonia.

Coke Kilns.—The last described process of making cokes, is now being superseded in many places, particularly in the neighbourhood of Sheffield, by the employment of kilns made of bricks, of a hemispherical form, about ten feet diameter at the base, and about two feet at the top, where a circular opening is left for the introduction of the coal. The manner of working these ovens is thus described by Mr. Parker:—"When these ovens are once heated, the work goes on night and day without interruption, and without any further expense of fuel. It is conducted thus: small refuse coal is thrown in at the circular opening at the top, sufficient to fill the oven up to the springing of the arch; it is then levelled with an iron rake, and the doorway on the side built up with loose bricks. The heat acquired by the oven in the former operation is always sufficient of itself to light up the new charge, the combustion of which is accelerated by the atmospheric air that rushes in through the joints of the loose bricks in the doorway. In two or three hours the combustion gets to such a height, that they find it necessary to check the influx of the air; the doorway is therefore now plastered up with a mixture of wet soil and sand, except the top row of bricks, which is left unplastered all night. Next morning, when the charge has been in twenty-four hours, this is completely closed also, but the chimney remains open till the flame is gone, which is generally quite off in twelve hours more. A few loose stones are then laid over the aperture, and closely covered up with a thick bed of sand or earth. All connexion with the atmosphere is now cut off, and in this situation the whole remains for twelve hours to complete the operation. The doorway is then opened, and the cokes are raked into iron wheel barrows, to be carted away. The whole operation takes up forty-eight hours, and as soon as the cokes are removed, the ovens are again filled with coal for another burning. About two tons of coals are put in for each charge, and the cokes produced are ponderous, extremely hard, of a light grey colour, and shine with metallic lustre; they acquire in the furnaces an intense heat, and will sustain a great burthen of iron-stone and other materials." When coke is required to be more of the nature of charcoal, the process is conducted in a different manner. The small coal is thrown into a large receptacle, similar to a baker's oven, previously brought to a red heat. Here the door is constantly open, and the heat of the oven is sufficient to dissipate all the bitumen of the coals, the disengagement of which is promoted by frequently stirring it with a long rake. The coke from the ovens, though made from the same kind of coal, is very different from that produced by the former operation, this being intensely black, very porous, and as light as pumice stone. Under the article Lime-Burning, a drawing and description of a patent oven for making coke is given, in which the latter operation is made subservient to the first. The mechanical arrangement and process therein exhibited, may be advantageously applied to the roasting of ores instead of lime, and the coke required for the smelting furnace might be made at the same time. As we have extended our observations on the making of coke from pit coal to a length which some of our readers may probably consider to be unsuited to its real importance, we would observe, in the language of Dr. Colquhoun, that the substance "has been the means of advancing the manufacture itself in this country, to an extent which is unparalleled in the history of any other country or nation. It has now been ascertained, by long experience, that there is no other fuel which is so well fitted at once to supply the heat of the furnace, and, at the same time, to endure the powerful blast which is incessantly forced upon it. It may now be said to be essential to our iron manufacture, which would, indeed, be almost annihilated were the supply of it withdrawn." Without it

we should be compelled to lay under wood immense tracts of what are now fertile corn fields, in order to supply, at an enormous expense, a much more imperfect fuel for the furnace. But the treasure of it seems to be inexhaustible, and not less so the metal for which it is required, as will be seen upon reference to the article Coal, wherein we have given a section of Bradley mine, and the arrangement of the numerous distinct strata cut through to arrive at the coal, amongst which there occurs from thirty to forty feet thickness of iron-stone, before the principal bed of coal is arrived at.

Roasting Iron-stone.—The ores of iron require different treatment in the smelting process, according to the nature and extent of the heterogeneous matter with which the metal is combined. In all ores the iron is in the state of an oxide, and would require a strong heat in contact with combustible matter for their reduction. In most species, the oxide of iron is combined with a considerable proportion of earthy or stony matter, and they are thence denominated iron-stones. But besides the earthy matter and oxygen, many of these contain sulphur, arsenic, and manganese; and it is necessary that these should be extricated previously to melting, which is effected by calcination, called *roasting.* This is usually done by stratifying the ore, broken into small pieces, with small or refuse pit coal, and burning it in great heaps, either in the open air, or in a kiln; which dissipates the sulphureous, arsenical, and other volatile matters, leaving behind the earth and oxide of iron, which are then easily broken into convenient fragments for melting.

Teague's Patent Roasting Furnaces.— Mr. Teague, of the Park End Iron Works, near Calford, in Gloucestershire, took out a patent in 1832, for improvements in smelting, in which he proposes to economise the process of roasting the ore, both as respects the labour and the fuel. Instead of making the calcination a distinct process, conducted in another part of the works, he combines the operations of roasting and smelting, which go on simultaneously in the same furnace. For this purpose he constructs around the chimney shaft, near to the top or tunnel-head of an ordinary smelting furnace, a series of four or more small reverberatory furnaces or ovens, each provided with a chimney, a damper at top, and a lateral door, which opens externally. Through these doors the ores to be roasted are introduced, and deposited upon iron plates, which form the bottoms, and incline downwards towards the shaft of the smelting furnace. The ascending body of flame from the latter, when at work, is prevented from passing out vertically, as usual, by means of a valve or trap door, which closes the orifice, and the small chimneys to the surrounding reverberatory roasting furnaces being opened, causes the flame and heated matters to pass through these, and in their progress to impinge upon the ore, and deprive it of its volatile combinations, When the ores have been thus sufficiently operated upon, they are thrust forward by a proper tool into the body of the smelting furnace; and whilst the roasting furnaces are being recharged, the valve or trap to the smelting shaft is opened, that the flames may take that course instead. Thus it would appear that a considerable saving

Fig. 1.

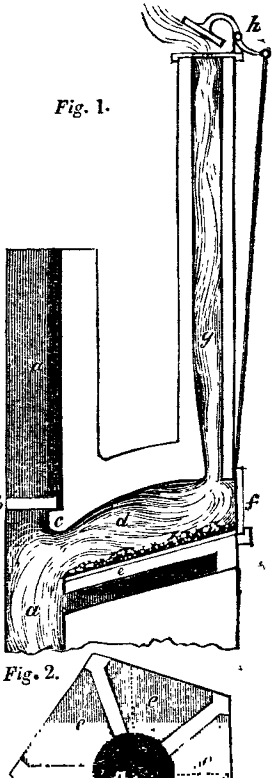


Fig. 2.

of labour is effected, and that all the fuel employed in roasting by the ordinary process is likewise saved, as the flame which usually passes out of the tunnel-head to waste in the air, is made to calcine the ore, and this being discharged into the blast furnace at the high temperature it had acquired in the oven, the subsequent fusion of it is greatly accelerated. In *Fig.* 1, on the preceding page, is given a vertical section of one of these roasting ovens, in connexion with the tunnel-head. *a a* represents a portion of the tunnel-head, or upper end of the blast furnace, provided with a door or valve *b*, resting on a ledge at *c*; *d* is one of the four ovens; *e* the iron plate that contains the ore or "mine," supplied through a doorway at *f*; *g* the oven chimney, with its damper *h*. *Fig.* 2 exhibits, on a smaller scale, a plan of the whole building, taken just above the oven plates, as designated by the four letters *e*; the fifth compartment *i* of the pentagon being for supplying the fuel and fluxes into the tunnel *a*, into which all of the compartments directly lead; each of these are closed externally by massive iron doors, suspended to stout iron lever beams to the opposite ends of which are hung counterbalancing weights, that enable the workmen to move them with facility. The dotted rectangle upon the plan is designed to explain the precise nature of the sectional view given in *Fig.* 1.

Jefferies' Coke and Iron Ore Furnace.—A patent for economizing the process of roasting ores was, however, taken out prior to the last-mentioned, by Mr. W. Jefferies, of Ratcliff, which was specified in August 1827. By this plan the roasting of the ore and the forming of the coke are performed together in one furnace; the process is thus described in the *Journal of Patent Inventions*, Vol. II. p. 66: "The ore is first broken by stampers, or crushed by rollers, until it is reduced to such fragments as will pass through a sieve of eight or ten holes to the square inch. After which, instead of introducing the pulverized ore into a roasting oven or furnace, it is incorporated with a sufficient quantity of small *coal*, and the mixture put into a coke oven, previously heated in the usual way. Herein the ore is calcined by the heat of the coal, the latter being thereby converted into coke; for this purpose the door of the oven is left open until all the flame has passed off, in the ordinary manner, when the door is to be closed, and all access of air prevented. After this the charge is to be withdrawn, as if it were coke merely, and, when cooled, broken down into masses of a proper size for the smelting furnace, into which it is thrown; the metal is here 'smelted out' from the coke with which it was combined; the coke serving as the fuel to fuse and extract it."

Fluxes.—The coke and iron-stone having been duly prepared, the next consideration is the nature and extent of the flux required to separate the metal by fusion from those of its combinations which the previous process was inadequate to perform. These differ in every degree and form, according to the nature of the ore, and as their consideration at length would occupy a greater space than the assigned limits of this work will afford, we purpose availing ourselves of a few extracts from the valuable papers by Mr. David Mushet, inserted in *Tillock's Philosophical Magazine*; and must refer those of our readers who may desire more information to the original source for it. "To deprive an ore of its iron" (says Mr. Mushet) "so that no portion of it shall escape in the scoriæ unrevived, two things are indispensable. First, the metal contained in the ore must be presented to a portion of fuel sufficient to take up the oxygen of the metal. Second, as this revivification goes on in the manner of a metallic perspiration upon the softened surface of the ore, another agent ought to be present to facilitate the separation by uniting with the earthy parts of the ore, forming a thinly divided lava, no longer capable of retaining the globules of metal, or of preventing the congenial affinity of the carbonic principle from taking full effect for the improvement of the quality of the iron."—"Experience has shown that an excess of any particular earth may be corrected by applying one opposite in its effects; and that the addition of lime, in various proportions, is found in most cases to answer the desired end."—"If the various classes of iron ore are fused in contact with charcoal, without the addition of a flux or solvent, the result is, from calcareous iron-stone, a larger portion of iron proportioned to the intrinsic richness of the ore, than from argillaceous iron-stone;

and from the latter a larger produce of iron, than from an ore whose chief mixture was silex; the scoriæ produced from the respective operations always demonstrate, from the colour and opacity, the probable quantity of iron which still remains to be taken up." There are some calcareous iron-stones which contain lime almost sufficient to form the necessary scoriæ, the colour of which, when freed from the metal, possesses a considerable degree of transparency. When a number of these stones are used in the blast furnace, a much less quantity of calcareous earths are necessary. It sometimes happens at iron works, whose chief supply is derived from a calcareous field of iron-stone, that by using a great proportion of an individual ore, surcharged with lime, the operations of the furnace are obstructed, and consequences entailed fatal to the interest of the manufacturer. From an excess of pure calcareous earth being present in the furnace, the scoriæ, thick and curdled, becomes attached to the sides and bottom of the furnace; the quantity hourly increases, till it has accumulated to such a degree as to intercept the ascent of the blast, and the descent of the materials. The remedy suggested by Mr. Mushet for these inconveniences, is, reducing the quantity of lime direct, or by an admixture of clay or sand, whether combined with iron or not. An excess of clay in the argillaceous ores has the same prejudicial effects which have led to their rejection, though it has been owing to improper application. The fusibility of lime and clay individually is much facilitated by the addition of sand. In all cases where these earths exist in excess in the ores, they ought either to be combined in the blast furnace with siliceous iron-stone, or treated with a lime-stone containing a considerable portion of sand. When a scarcity of lime exists in the blast furnace, and a superior quantity of clay and silex is combined with the iron-stones, the lava will flow from the furnace comparatively cold, tenaceous, and of a brown or pale dirty green colour, containing iron; when the mixture is just, the colour of the scoriæ is pure white, enamelled with a variety of blue shades, waving, circular, or formed in straight delicate lines, arising from a peculiar existing modification of a minute portion of the metal. Where nature has bestowed mixtures productive of every quality of crude iron, the proper management of ores would become simple and easy: just combinations supersede the necessity of changing the quality of the lime-stone added for a flux, or of having recourse to various qualities of it, in order to assist or correct the deficiency of the native mixture. Wherever the ores are of a structure thus deficient, it then becomes the province of the manufacturer to ascertain the mixture of the individual ores which compose his supply, and to restore that equilibrium of parts by the proper application of superadded earths which experiment and observation have proved to determine a certain quality of iron.

Many years ago, Messrs. Hill and Co. of the Plymouth works near Merthyr, took out a patent for the use of the "cinder" produced in the refining and puddling operations, as a substitute for a portion of mine in the smelting process. This cinder or scoriæ is an oxide of iron combined with but little foreign matter, and usually contains from 50 to 70 per cent. of metal. All previous attempts to smelt it economically had failed. Messrs. Hill and Co. mixed with it such a portion of argillaceous matter as to assimilate it to the natural ore of their district, and by this combination succeeded in its perfect reduction. The patent was soon after invaded; and, upon an action being brought for infringement of right, the defendants proved a prior application of the process. The patent was thereby quashed, and the iron masters, in consequence, generally adopted the process; but, from injudicious management, much bad iron was made, which got it into disrepute. With proper care, and in small proportion, the cinder is now used advantageously at most of the iron works, in the making of forge-pigs, under the subsequent process of puddling. It is usual, in most furnaces, to make the coke always a fixed quantity, and to proportion the iron-stone and the lime or other flux, to the quantity of iron to be made, and the working order of the furnace; and in proportion to the latter additions, the furnace is said to carry a greater or less burthen. Some furnaces carry so little burthen as to produce only about 13 tons per week, while there are others which yield as much as 70 tons per week. In these latter, the ore is in much

greater proportion to the coke than the former, but the product is inferior. The burthen is varied according as the iron is required to possess more or less carbon; thus in making No. 1, or best iron, (which contains the greatest proportion of carbon, the burthen must be considerably less than that required to make less carburetted iron, or what is called white-iron, or forge-pig. A general idea of the proportions of the materials from an argillaceous ore, containing about 27 per cent. of iron, with a strong carbonaceous coal, and a good limestone, consisting of shells, is afforded by the operation of a furnace under Mr. Mushet's direction. The furnace works with a bright tuyere, and receives from the blast about 2500 cubic feet of air per minute, through a circular aperture 2¾ inches in diameter. The quantity of calcined ore for the manufacture of good melting iron is upon a par with the coke; and forge-pig, or the least carburetted variety, six of coke to seven of ore. The lime-stone, unburnt, under the same circumstances, is to coke as 4 to 11; and for melting metal, retains a similar ratio.

Smelting Furnace.—The external figure of a blast furnace is that of a truncated pyramid, while its interior form has been very aptly compared to that of a decanter, supported upon a funnel. In the subordinate details of their construction, there is much variation by different iron masters, which, however, probably does not essentially affect the results. In the annexed sectional representation of one of these great laboratories, we have not selected one of

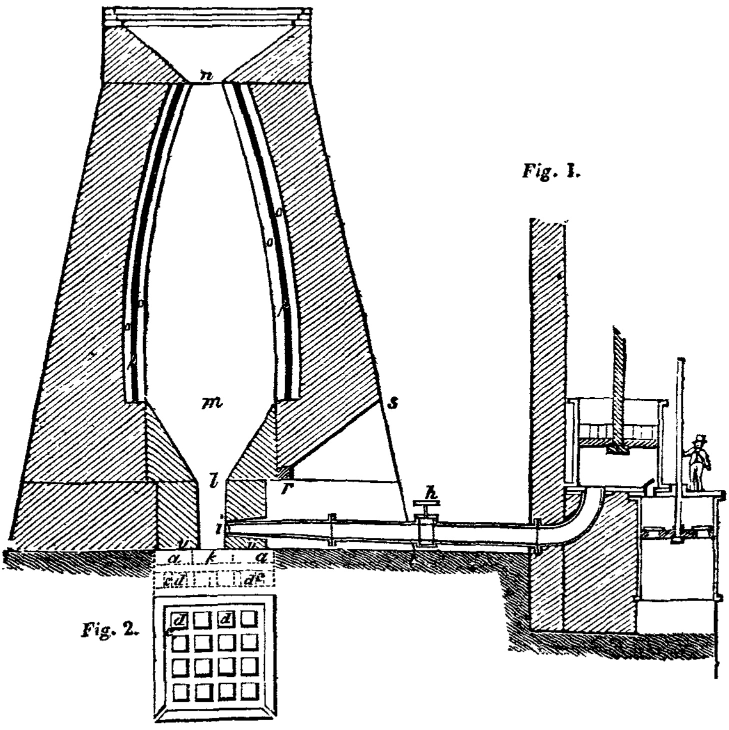


Fig. 1.

Fig. 2.

the latest mould, but one that was described and found to be very efficient by that great master in metallurgic operations, Mr. David Mushet; since which, we believe there have been no improvements of essential importance, except in the blowing machinery, which we shall duly notice. *a* is the regulating cylinder, 8

feet in diameter, and 8 feet high; *b* the floating piston, loaded with weights proportionate to the power of the machine; *c* the valve by which the air is passed from the pumping cylinder into the regulator; *d* the aperture by which the blast is forced into the furnace; diameter of the pipes, 18 inches; *e* the blowing or pumping cylinder, six feet diameter, 9 feet high, 7 feet stroke; *f* its piston, with a view of one of its several valves; *g* solid masonry, on which the regulating cylinder rests, and to which the flanch and tilts of the blowing cylinder are attached. *h* the safety-valve or cock, by the simple turning of which, the blast may be admitted to, or shut off from the furnace, and passed off to a collateral tube in the opposite side. *i* the tuyere, by which the blast enters the furnace. The end of the tapered pipe, which approaches the tuyere, receives small pipes of various diameters, from 2 to 3 inches, called nose pipes, which are applied at pleasure, according to the strength of the blast required. *k* is the bottom of the hearth, 2 feet square; *l* the top of the hearth, 2 feet 6 inches square; *k l* the height of the hearth, 6 feet 6 inches; *l* is also the bottom of the boshes, which here terminate, of the same size as the top of the hearth, only the former are round and the latter are square. *m* the top of the boshes, 12 feet in diameter, and 8 feet high; *n* the top of the furnace, 3 feet diameter, at which the materials are charged; *m n* the internal cavity of the furnace of the top of the boshes upwards, 30 feet high. *n k*, total height of the internal parts of the furnace, 44½ feet; *o o* the lining, which is built with fire bricks, 13 inches long by 3 thick, in the nicest manner; *p p* a vacancy left all round the outside of the first lining, 3 inches wide, which is rammed full of coke dust, this space being left for the expansion of the materials by heat; *q q* a second lining, similar to the first; *r* a cast iron lintel, in which the bottom of the arch *r s* is supported—this arch is 14 feet high on the outside, and 18 feet wide; *v v* the extremes of the hearth, 10 feet square. *Fig.* 2 represents a plan of the foundation of the furnace; *a a* are the bottom stones of the hearth; *b* stratum of bedding sand; *c c* passages for the escape of vapour; *d d* pillars of brick; these parts, in the dotted elevation, are indicated by similar letters of reference. The subjoined, *Fig.* 3, affords an horizontal section of the diameter of the boshes, the linings and vacancy being indicated by similar letters of reference to those in the elevation. *Fig.* 4 exhibits a vertical side section of the hearth and boshes, showing the tymp and dam-stones, and the tymp and dam-plates. *a* the tymp-stone; *b* the tymp-plate, wedged firmly to the stone, to hold it in case of splitting by the heat; *c*, dam-stone, which occupies the whole breadth of the bottom of the hearth, excepting about six inches, which, when the furnace is at work, is filled every cast with strong sand. This stone is surmounted by an iron plate of great thickness, called the dam-plate, the top of which is about 3 inches below the tuyere hole. The space between the bottom of the tymp and the dotted line is rammed full of strong sand or fine clay, called the tymp stopping, which prevents any part of the blast being wasted. The square of the base of this blast furnace is 38 feet; the height from the false bottom to the top of the crater, 55 feet.

Fig. 3.

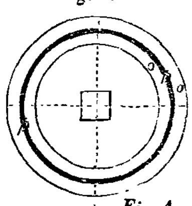
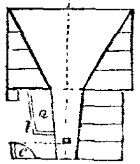


Fig. 4.



Mode of working furnace.—When the furnace is finished, the bottom and sides of it for 2 feet up the square funnel, receive a lining of common bricks upon edge, to prevent the stone from shivering or mouldering when the fire comes in contact with it. On the front of the furnace is erected a temporary fire-place, about 4 feet long, into the bottom of which are laid corresponding bars. The side walls are made so high as to reach the under surface of the tymp-stone. A fire being kindled upon the bars, the whole cavity of the furnace serves as a chimney; the draught and heat is therefore considerable. In the course of three weeks, the furnace is freed from damp, and ready to receive the materials; the fire-place is then removed, but the interior brick

lining remains till the operation of blowing commences. Some loose fuel is then thrown upon the bottom of the furnace, and a few baskets of coke, which are allowed to become thoroughly ignited before more are added, and the furnace is then gradually filled. The furnace represented is capable of holding 99,000 lbs. of coke, equivalent to 198,000lbs. of coal. This quantity of materials is continually burning for several years together, without intermission! A renewal of the total quantity occurs about every third day. There are, nevertheless, still larger furnaces in Wales. The first charges which a furnace receives contain but a small proportion of iron-stone compared to the weight of the coke, which is afterwards increased to a full burden. The descent of the burden is facilitated by opening the furnace below, two or three times a day, throwing out the cold cinders, and admitting, for an hour at a time, a fresh body of air. This operation is repeated till the approach of the iron-stone and cinder, which is always announced by a partial fusion, and the dropping of lava through the iron bars, introduced to support the incumbent materials while those in the bottom are carried away. The filling above is regularly continued; and when the furnace at the top has acquired a considerable degree of heat, it is then judged time to introduce the blast; the preparations of which are the following:—The dam-stone is laid in its place firmly imbedded on fire-clay; the dam-plate is again imbedded in this with the same cement, and is subject to the same inclination. On the top of this plate is a slight depression, of a curved form, towards that side farthest from the blast, for the purpose of concentrating the scoriæ, and allowing it to flow off in a continued stream, as it tends to surmount the level of the dam. From this notch to the level of the floor a declivity of brick-work is erected, down which the scoriæ of the furnace flows in large quantities. The opening betwixt the dam and side walls of the furnace, called the *fauld*, is then built up with sand, the loose bricks are removed, and the furnace bottom is covered with powdered lime or charcoal dust. The ignited cokes are now allowed to fall down, and are brought forward with iron bars, nearly to a level with the dam. The space between the surface of the cokes and the bottom of the tymp-plate is next rammed hard with strong binding sands; and these cokes, which are exposed on the outside, are covered with coke dust. These precautions being taken, the tuyere hole is then opened and lined with a soft mixture of clay and loam; the blast is commonly introduced into the furnace, at first with a small discharging pipe, which is afterwards increased as occasion may require. In two hours after blowing, a considerable quantity of lava is accumulated; iron bars are then introduced, and perforations made in the compressed matter at the bottom of the furnace; the lava is admitted to all parts of the hearth, and soon thoroughly heats and glazes the surfaces of the fire-stone. Shortly after this it rises to a level with the notch in the dam-plate, and by its own accumulation, together with the forcible action of the blast, it flows over. Its colour is at first black; its fracture dense, and very ponderous; the form it assumes in running off is flat and branched, sometimes in long streams, and at other times less extensive. If the preparation has been well conducted, the colour of the cinder soon changes to white; and the metal, which is in the state of an oxide formerly coloured, will be left in a disengaged state in the furnace. When the metal has risen to nearly a level with the dam, it is then let out by cutting away the hardened loom of the fauld, and conveyed by a channel made in sand to its proper destination; the principal channel, or runner, is called the *sow*, the lateral moulds are called the *pigs*; hence the name of the raw commercial article, "pig-iron," of which many hundred thousands of tons are annually made.

Phenomena attending the production of the different qualities of Pig-metal.—When fine (No. 1,) or super-carbonated crude iron is run from the furnace, the stream of metal, as it issues from the fauld, throws off an infinite number of brilliant sparkles of carbon. The surface is covered with a fluid pellicle of carburet of iron, which, as it flows, rears itself up in the most delicate folds; at first the fluid metal appears like a dense ponderous stream, but as the collateral moulds become filled, it exhibits a general rapid motion, from the surface of the pigs to the centre of many points. Millions of the finest undulations

move upon each mould, displaying the greatest nicety and rapidity of movement, conjoined with an uncommonly beautiful variegation of colour, which language is inadequate justly to describe. Such metal, in quantity, will remain fluid for twenty minutes after it has run from the furnace, and, when cold, will have its surface covered with beautiful carburet of iron, already mentioned, of an uncommonly rich and beautiful appearance. When the surface of the metal is not carburetted, it is smooth, like forged iron, and always convex. In this state iron is too rich for melting without the addition of coarse metal, and is unfit to be used in a cupola furnace for making fine castings, where thinness and a good skin are requisite.

No. 4, or oxygenated crude iron, when issuing from the blast furnace, throws off from all parts of the fluid surface a vast number of metallic sparks, and, while running, it is covered with waving flakes of an obscure smoky flame, accompanied with a hissing noise. This is a slight sketch of the appearances of the two extreme qualities of crude iron, when in a state of fusion. There still remain two intermediate stages of quality to be described; these are, carbonated, and carbo-oxygenated iron, that is, No. 2 and No. 3 of the manufacturers.

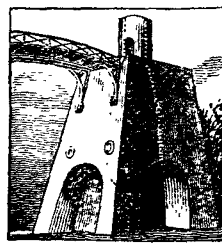
No. 2, or carbonated iron, exhibits, like No. 1, a beautiful appearance in the runner and pig. The breakings of the fluid, in general, are less fine, the agitation less delicate, though the division of the fluid is equal, if not beyond, that of the other.

No. 3, or carbo-oxygenated iron, runs smoothly, without any great degree of ebullition, or disengagement of metallic sparks. The partings upon its surface are longer, and at greater distances from each other than in the former varieties; the shape they assume is either elliptical, circular, or curved. In cooling, this metal acquires a considerable portion of oxide. An infallible criterion of the quality of the iron in the furnace is afforded by the colour of the scoriæ upon the working bars, which are from time to time inserted to keep the furnace free from lumps, and to bring forward the scoriæ. When No. 1, or super-carbonated iron, is on the hearth, the vitriol crust upon the bars will be of a black colour and smooth surface, fully covered with large and brilliant plates of plumbago. As the quality of the metal approaches to No. 2, (carbonated,) the carburet upon the scoriæ decreases both in point of quantity and size. When carbo-oxygenated (No. 3) is in the furnace, the working bars are always coated with a lighter coloured scoriæ than when the former varieties exist; a speck of plumbago is now only found here and there; and when the quality of the metal is oxygenated (No. 4), not only have the plates of carburet disappeared, but also the crally colour on the external surface of the scoriæ. It may perhaps be proper here to mention, that although for convenience the manufacturer has, from a just estimation of the value of the metal in a subsequent manufacture, affixed certain numbers for determinate qualities of iron, yet it is difficult to say at what degree of saturation of carbon each respective term commences; suffice it then to say, that the two alterative principles, oxygen and carbon, form two distinct classes—that in which oxygen predominates, and that in which carbon predominates.

Mechanical arrangements for supplying the tunnel-head with the materials for fusion.—The mode of supplying the lime, coke, iron-stone, &c. to the crater, or tunnel-head of the furnace, was formerly by men carrying them in baskets up an inclined plane or bridge. Subsequently small waggons or corves were employed to take the materials up an inclined railway to the crater, by means of chains connected to the waggons, and passing round a drum or rigger, actuated by the steam engine, or other prime mover. In some instances the weight of a bucket of water descending into a pit was employed as the moving force to draw the loaded corve up to the top of the furnace, or hopper leading into it; where the corve, by being provided with a sliding bottom, to which was fixed a projecting bar, discharged its contents, by the bar coming against an obstruction, which pushed the bottom away, when over the discharging hole. The bucket also, on reaching the bottom of the pit, was discharged of its water, through a valve in its bottom being opened by coming in contact with a

projecting pin at the bottom of the pit. The motion was then reversed by the superior weight of the empty waggon, causing it to descend the inclined plane, and raise up the empty bucket for a renewal of the operation, by refilling the vessels, one with the mineral, and the other with the water. In some situations the mode of raising the materials is by an endless chain passing round two riggers, one at each extremity of the inclined plane, the chain carrying two corves or buckets, one of which is being filled below whilst the other is being discharged above, in continuous succession; in a similar way to the scoops in dredging and excavating machines, described under their initial letters.

Welsh Smelting Furnaces.—In South Wales and other mountainous districts they usually contrive to build their blast furnaces beside cliffs or steep precipices, which are sometimes walled up artificially to render them perpendicular, so that the tunnel-heads of the furnaces shall be upon a level or somewhat lower plane than the contiguous high ground, from which a bridge is thrown on to the top of the solid masonry, after the manner expressed in the subjoined cut. This cut also gives the external form of the furnace described at page 758, with this difference merely, that instead of the open crater or tunnel-head, this has a vertical cylindrical chimney of the same internal area as the upper orifice built over it; on one side of which there is a doorway for charging the furnace with the mine and other materials. A parapet wall or iron fence surrounds the upper edge of the square tower. The dotted lines in the figure indicate the form of the interior of the furnace. The coke-hearths and the mine-kilns, and all other supplies to the furnace, are situated on the high ground, so that they can at once be shot across the bridge into the tunnel-head. Various buildings, including the "cast-house," where the metal is run into pigs (or other forms to patterns as may be required) are situated on the lower level, and are covered with roofs.



Anthracite used in Smelting.—Before closing our account of the smelting department of the iron manufacture, we think it right to call the attention of those who are interested in the iron trade to the consideration of the practicability of employing anthracite, or stone coal, in the process of smelting. In several parts of Great Britain and Ireland, but particularly in Scuth Wales, there are many thousands of acres of iron-stone near the surface, with a vast abundance of anthracite coal, lying in contiguous strata. This coal, notwithstanding it consists almost entirely of carbon, has been alleged, and is generally believed, to be incapable of smelting iron; and as there are in some districts (that of Llanelly, for instance,) no bituminous coal sufficiently near to these valuable beds of iron-stone, they remain unworked, under the presumption that they *cannot* be worked with profit, owing to those circumstances. Whether this prejudice is well or ill-founded, is a question that we cannot take upon ourselves to solve; but we will place before the reader a few facts that appear to bear directly upon the question, and leave the solution to those who are more practically conversant with the subject.

In several parts of the United States of America, where (as in South Wales) iron-stones and anthracite are plentiful, but bituminous coal wanting, recent attempts have been made to smelt the iron with anthracite alone; and all the reports that have reached us on that subject agree in stating that success has attended those attempts.

Malin's Furnace for Smelting Iron with Anthracite Coal.—Mr. Joshua Malin, of Lebanon, in Pennsylvania, has described his furnace for this purpose in the *Franklin Journal.* It is very similar to our common blast furnaces, the crucibles and hearth alone differing materially. Mr. Malin's crucible, instead of being square is round; anthracite coal being so much more dense than coke or charcoal, its weight causes it to descend in the corners or angles of a square hearth, where, being screened from the intense blast which is required, and carrying with it a portion of the unmelted ore, it mixes with, and chills a quantity of the fused ore and metal, which stops the operation of the furnace.

For the smelting by means of anthracite, Mr. Malin states, that the blast must be introduced under a pressure of at least two and a half pounds to the circular inch; and the quantity required for a common sized furnace will not be less than 28,000 cubic feet per minute, or 7 cubic feet per minute for every circular inch in the area of the hearth at the tuyere. The hearth of the furnace in which Mr. Malin made his experiments, was only 11 inches in diameter at the tuyeres, the blast being introduced as represented in the subjoined plan. Mr. Malin had the diameter increased to 14 inches, and found that the blast which he had at his command would not enable him to go beyond that point, as, when he attempted it, the scoriæ and metal chilled, and formed a tube from the tuyere a part of the way across the hearth. *Fig.* 1 exhibits a vertical section, and *Fig.* 2 an horizontal section drawn to a scale of an eighth of an inch to the foot; the letters of reference in each figure that are the same indicate

Fig. 1.

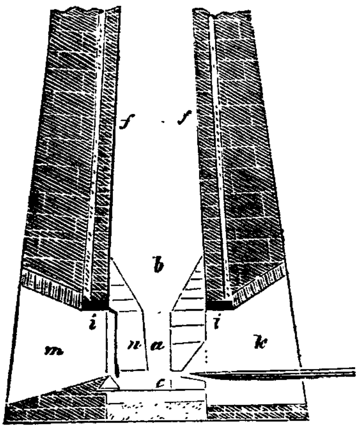
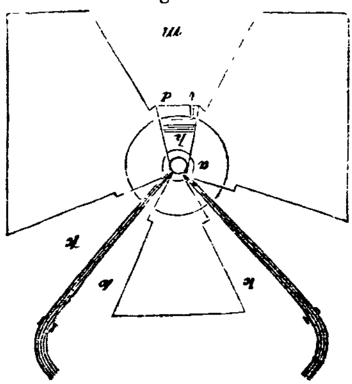


Fig. 2.



corresponding parts. *a* is the crucible, being a part of what is commonly called the hearth of the furnace; *b* are the boshes, or that part where the metal passes from the solid to the fluid state as it descends; *c* is the bottom stone of the hearth, bedded in sand, and supporting the crucible and boshes; *d* is the dam-stone; *e e* the blast pipes; *ff* inner walls of the furnace of fire-brick, around which is a space from 4 to 6 inches wide, filled with soft sand-stone; *h* tymp-plate; *i i* lintels of cast-iron to support the inner walls over the tuyere and tymp-arches; *k k* tuyere arches; *l* part where the metal flows out; *m* tymp arch; *n* the tymp-stone, forming a part of the crucible, and supporting a part of the boshes.

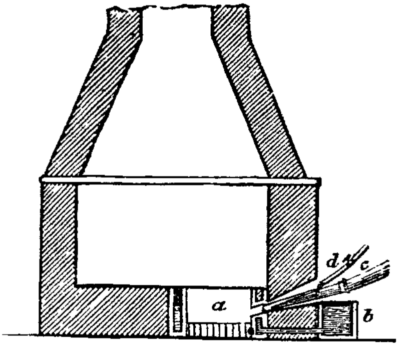
The prejudices in America against the use of anthracite were as strong as they are here; but there they are now being rapidly dissipated by an irrepressible spirit of enterprise, guided by scientific intelligence; whilst we, out of reverence to the ignorance of our forefathers, adhere to and cherish them. In America anthracite was at first introduced into the parlour grates, where, having gained a triumph, it descended into the kitchens, in spite of the vehement protestations of the ministers of the victualling department; having, however, here demonstrated its superiority over all other kinds of fuel, it next presents itself to the notice of stea-furnace men and the iron masters; these, however, asserted that there was something in its *very nature* which, in their occupations, forbade its use; and they were so obdurate, Dr. Jones informs us, that "you might as well have attempted to convince them that it was fit to be made into candles,

as that it might be employed for their purposes if their furnaces were suitably constructed, and the fuel properly managed." "It appears likely, however," our scientific historian continues, "that it will soon assert its claims to superior excellence in these applications also, and triumph over the prejudices of the managers of furnaces, as it has over those of the householder, the cook, and the blacksmith."

Improved Blowing Machinery.—In continuing our accouut of the process of obtaining iron in the smelting furnace, we omitted to notice that the blowing apparatus delineated in connexion therewith, has, in a great measure, been superseded by improved mechanism of that kind. The pumping cylinder, by an arrangement of valves well understood, is made to draw air on both sides of the piston, so that whilst the air enters on one side it is forced out on the other into the regulating vessel, from whence it is usually conducted into the furnace by two or three distinct pipes and tuyeres. But a most ingenious arrangement of blowing cylinders was invented by Mr. Paterson, of Lanark, which is described and figured in the article Blowing Machines, wherein several others are given. Water bellows have been extensively employed, but the objection to these has been the humidity which the air acquired by the spray; to remedy this defect, the air is forced into a dry regulator, which is simply a large air-tight metal box, about 10 feet square and 40 feet long. At Bradley iron works they have a regulating cylinder of still greater dimensions. The uniform elasticity which the air acquires in these great chambers causes it to issue in a constant equalized blast.

The blowing of heated air has recently been introduced at several foundries, and likewise at the Clyde iron works. It is the invention of Mr. J. B. Neilson, of Glasgow, whose patent was enrolled in March, 1829, and is designated an improved application of air to produce heat in fires, forges, and furnaces, where bellows or other blowing apparatus is required. He proposes that the air supplied by any kind of machine shall, before it enters the furnace or cupola, be made to pass through an air-vessel heated to very high temperature, a red heat if possible, by which means a current of hot air will be thrown on the fire instead of the cold current usually employed. It is recommended that the air vessel be surrounded with some non-conducting substance, and imbedded in masonry. The capacity of this vessel for a smith's forge he recommends to be about 1,200 cubic inches, and for a cupola or blast furnace, about 10,000 cubic inches. It was much doubted whether the increased temperature of the fire thus blown would produce advantages equivalent to the expense of constructing the air vessel and keeping it at the requisite heat; and as respects the smelting of iron in particular, the theory seemed opposed to the well-known fact that a much larger quantity of iron is yielded by the blast furnaces in the winter season, or when the air is cold, than during the summer season, when the air is warm. The experiments at the Clyde iron works, have however been reported most favourably of, and the saving of coal attending it is so great, that it was stated, in the *Glasgow Chronicle*, to be calculated to accomplish a saving in the consumption of this island to the amount of 200,000*l.* annually. At the Clyde iron works the air was heated to 220° Fahr. before it was discharged into the furnace; an effect which was produced by the expenditure of only one-eleventh part of the cost of fuel it takes to heat it to the same temperature in the blast furnace, which may be accounted for by the circumstance that Mr. Neilson's air vessel is heated by coals, while the blast furnace is heated by coke. Should further experience in this invention confirm the views of the patentee, it may be regarded as a valuable improvement in metallurgic operations.

Refining Furnace.—The refining of pig-metal is a modern intermediate process of conversion, which the experience of our iron masters has led them to believe is the best economy in the preparation of the metal for being subsequently rendered malleable in the puddling furnace, although it is well understood to be unnecessary to the production of wrought iron. The furnaces employed for this purpose are small buildings, termed refineries; a vertical section of one of them is given in the cut on the next page. *a* is a thick cast-iron trough, having three of its sides made double, with a hollow space between,



around which water is caused to flow from an external cistern *b*, the cooling effect of the fluid serving to prevent the fusion or other injury of the metal sides of the furnace by the intense heat; at *c* (in a line) are two pipes, through which air is forced from a blowing machine upon the materials in the trough; these pipes are kept cool by a constant stream of water always flowing over them, brought on by small pipes *d*, regulated by cocks. The bottom of the furnace is of brick, on which the fuel is laid, and over it the pigs to be refined. The building is surmounted by a wide chimney about 12 feet high, and the front, which is left open, has a projecting roof to cover the workmen who attend to it. In Wales it is usual to make these furnaces what is termed *double;* that is, the fire is somewhat larger though single, but the blast is double, there being usually three pipes and tuyeres on each of two opposite sides of the furnace; each of the pipes are generally about an inch in diameter, and supplied with a blast equal to about 2 or 2¼ lbs. pressure upon the square inch. The pigs are kept in a state of fusion for some time, exposed to an intense heat from the powerful blast just mentioned, which drives off a portion off the carbon united to the metal. When the operation, which usually occupies two hours, is deemed to be complete, a hole in front of the hearth is tapped, through which the liquid metal flows into a very thick oblong flat mould of cast-iron, placed over a cistern of water; this causes the metal to be rapidly chilled, which is thus brought into a cake about 2 feet broad and 20 feet long. This plate of metal is extremely brittle, and presents on its fracture a silvery whiteness: it weighs about a ton. In some refineries the furnace is lined with firebricks or stones, without water running round it, and the refined metal is cast upon sand in shallow moulds or depressions, and water is then thrown upon the metal to cool it quickly. As inattention or neglect on the part of the refiner would be productive of serious loss to the iron master, he is always paid according to the metal produced. Great experience and practical skill are requisite qualities in a refiner; his occupation is one of great personal exertion, and he is exposed to an intense fire, that no one unaccustomed to it could even approach. He puts the charge of pigs upon the fire, attends to the progress of the melting, supplies the fire from time to time with coke, frequently stirring it up to equalize the heat; sees that the tuyeres are in good order, and that the water circulates uninterruptedly; runs out the metal when it is ready; he removes the plate from its mould when it has a little cooled, by means of a lever, on to a truck, and wheels it out of his shed; he then prepares his mould for the next plate, removes his cinders, and repeats the operation. The quantity of refined metal thus produced by a "double" furnace in Wales, is from 60 to 70 tons per week, of 6 days of 24 hours each, the men working in turns of 12 hours at a time, and 12 hours rest. The refiner selects his materials according to the quality of iron wanted. The best quality is from the dark grey pig, or No. 3, and the inferior sorts from bright, mottled, and white in their order. The very "worst" white iron cannot be used by itself in the refinery; being almost infusible from its deficiency of carbon, it is disposed to clog and settle on the hearth. To work up such iron in the refinery, it is mixed with pigs of a "better quality," or those containing more carbon, the union conferring fusibility. When No. 3 pigs are used, it requires about 22½ cwt. of them to produce one ton of refined metal; the "yield" however varies, from causes before adverted to, according to the degree of carbonation of the pig metal employed, the quality of the coke, the management of the blast, and various other circumstances. This reduction of weight is however not an entire loss, as a quantity of

"cinder" is produced which floats on the top of the metal, and detaches itself as it cools; this cinder contains usually about 50 per cent. of its weight of iron, which is recoverable on the blast furnace.

The Puddling Furnace.—The next process consists in depriving the iron of its remaining carbon and oxygen (or as far as that may be practicable), by which it is rendered malleable and is constituted wrought-iron. For this purpose the brittle plate of white refined iron is broken up into small pieces, and brought to the puddling furnace, sometimes called the balling furnace, from the circumstance of the iron being therein made up into balls, about the size and shape of quartern loaves of bread. The furnace differs but little from an ordinary reverberatory furnace, as will be seen upon reference to the subjoined engravings, in which *Fig.* 1 exhibits a vertical and longitudinal section, and *Fig.* 2 an horizontal section or plan. As a strong flaming fuel is required in this operation, coal is employed in preference to coke, the gaseous portion of the former being rendered available as fuel. At *a* is the ash-pit; *b* a series of

Fig. 1.

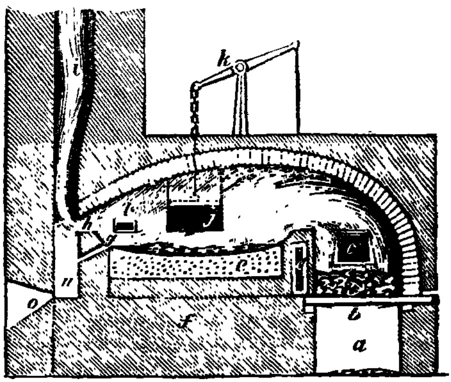
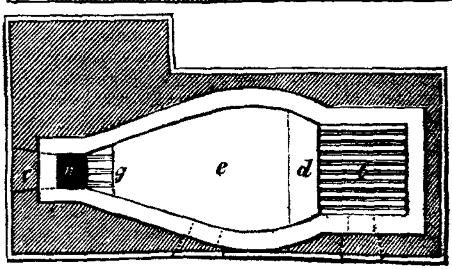


Fig. 2.



loose grate-bars, on which is deposited the coals introduced through an aperture *c* kept closed, except during the charging or stoking, by heaping up the small coal against it externally, where it is formed into a cast-iron receptacle for the purpose, resembling a coal scuttle; at *d* is the fire-bridge, frequently made hollow by an iron casting, as shown in the drawing, and encased with fire-bricks; this hollow casting is connected externally with a vertical pipe to convey off the air, which is caused to pass through the fire-bridge; and by the heat it thus abstracts, the fire-bridge is prevented from becoming fused by the intense action of the flame. At *e* is the basin of a bed of sea sand spread into a concave shape; it is supported upon a stratum of fire-bricks, which lie on solid masonry *f* beneath. On this bed the refined metal is placed and exposed to the heat of the flames, which are made to impinge downward upon the metal in a constant stream, owing to the curved form of the roof, against

which the current of air that passes through the grate-bars strikes; from the metal the flames again ascend, passing over a dam *g*, through the throat *h*, into the chimney *i*, which is carried up from 30 to 40 feet high, and is provided with a damper at the top, by which the puddler regulates the degree of draft, and consequently the heat of his furnace; for during some parts of his operations, he requires a more intense heat than at others. The draft through these furnaces is frequently so great as to cause the flames to ascend above the chimney top, and to make the damper, situated there, red hot. At *j* is a sliding door, suspended by a chain, and raised or lowered by a lever *k*; at the bottom of the door is a small aperture (as shown in *Fig.* 1) employed as a spy-hole, and for the introduction occasionally of the puddler's tools without opening the door. There is also usually another small aperture at *l*, lined with a cast-iron box or case, and divided by a partition into two cavities, through which the "shingler" puts his iron bars to be heated, as will be hereafter explained. The dam *g* before mentioned is deeply grooved or furrowed (as seen in *Fig.* 2) to allow the cinder or slag to run off into a pit *n*, whence it is discharged through an opening *o* out of the furnace. The chimney is bound together at different points with iron, and the external sides of the body of the furnace is encased in iron plates, bolted through the brick-work. All these precautions are, however, insufficient to prevent the early distortion of the fabric, and which would without them soon fall into ruins by the destructive effects of the fire. The employment of a sand bottom to the furnace, it is proper to mention, is now getting into disuse in many parts, where, in lieu of the sand, a thick cast-iron plate forms the bottom, on which is strewed a coat of the oxide or cinder made in the puddling process. The puddler is assisted in all his operations by an inferior workman, termed his "under-hand," who is not recognised by the master, but paid by the puddler. The metal being put into the furnace, the door is shut down and carefully closed to prevent the admission of air, as any admission of air otherwise than through the grate-bars, tends to derange or moderate the proper current. In about half an hour the metal begins to fuse, at which time the severe labours of the puddler begin. His first business is so to dispose the pieces of melting metal, that those which are the least exposed to the action of the flame may be drawn more immediately under its influence, and that the whole quantity may be brought to the same fluid state, as nearly as possible at the same time. If it is not so managed, that which is first melted begins to burn and waste before the other is ready, and the yield is therefore inferior than when all goes on well together. When the whole is melted, the puddler, sometimes with a tool turned at the end like a hoe, and sometimes with a flat one, stirs it about diligently in all directions, exposing every part of it in turn to the action of the flame. In doing this he is obliged to be constantly changing his tools, which soon become red hot, and are plunged, as they are withdrawn, into a vessel of water to cool them. The liquid mass heaves and boils as it is being stirred, showing the escape of elastic fluid. By degrees the metal loses its fluid property, and assumes the appearance of a loose granulated mass, the external particles of which appear in vivid combustion, whilst the main portion of it is less brilliant; these appearances indicate that the metal is "coming round to nature," as the puddler terms it; and to accelerate this process, he frequently throws some water from a scoop on to the metal, and occasionally adds a portion of the black oxide of iron formed in the subsequent processes of the forge, by which the weight of his product of metal is increased. He continues to move the mass about vigorously till it becomes so thick and tenacious as to stick together and form into lumps. At this time the puddler with great dexterity, exposed to a severely scorching heat, and a light of the most dazzling brilliancy (which no ordinary person can even look at but for an instant), separates the metal into masses resembling in size and figure quartern loaves of bread, but weighing from 50 to 80 lbs. each, called "puddled balls," and having arranged his batch of metal upon their vitrified bed, they are left there exposed to the continuation of the heat, until they can be successively extracted and delivered by the under-hand to the shingler. By this mode of puddling, a loss of time is incurred, by the heating of the fresh metal for the

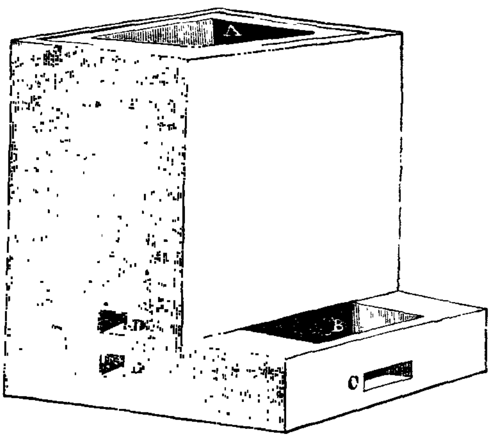
next batch, amounting to nearly half an hour, besides the waste of fuel during that period. To obviate these losses, various contrivances have been resorted to for heating the fresh charge of metal, whilst the previous batch of puddled balls are being shingled or rolled. The simplest and most improved plan deserves mentioning. It is merely to make the body of the furnace longer than usual, and to have a second door between that where the puddler works and the chimney. This affords sufficient room for the succeeding charge of metal, which is at the same time so near the workman that when he has completed the heat and sent the balls to the shingler, the newly-prepared charge is just in the right state for him to bring forward and recommence his operations upon. By the puddling furnaces first described, but seven heats could be completed in the turn of twelve hours; but with the improved furnace, nine heats are effected in the same time by one puddler, the results being two-ninths more of iron, without any additional quantity of coals.

Malleable iron produced direct from the ore with stone coal.—A short time ago, a patent was taken out in America, by Mr. B. Howell, of Philadelphia, for an improvement in a "bloomery furnace," "*by means of which, and the use of anthracite coal exclusively for fuel, iron ore is directly converted into malleable iron.*" As this invention would be of immense importance to the country, if it could be brought successfully into operation, (and we can discover no reason why it should not,) we deem it right not to omit giving a description of it in this work.

The specification, after adverting to the drawings, states, "By these, and the notes and references appended thereto, it will be seen that this furnace combines within itself the advantages of a close furnace and an open fire; in this respect differing essentially from any other now in use for similar objects. In the upper or close portion, being all that above the hearth, with anthracite coal excited by a proper blast, a degree of heat is obtained much greater than can possibly be generated in the ordinary fire with charcoal; while the lower portion opening into the hearth, and permitting the free action of blast upon the burthen, performs all the offices of the open fire, or forge. The size of the furnace and the proportions may be varied, if the principle of the close and open fire be retained. The furnace being first heated up in the manner of a common cupola, the process is thus conducted: the coal having settled sufficiently for that purpose, it is charged with the proper burthen of ore, which will vary according to the quality and kind. The charges are then continued alternately of coal and ore. The ore soon arrives at the tuyeres in a state of partial fusion, and is then, by the intense heat of that part of the furnace, quickly separated from its earths, and then rapidly descending into and below the direct action of the blast, a large part of which is driven out at the open front, first passing over that portion of the ore which has reached the hearth, it is thereby brought, in the language of the workmen, "to nature," or, in other words, into malleable iron. As it sinks into the region of the blast, the small masses may be driven into one, and a loup shaped by giving a proper direction to the pipes at the different tuyeres, and the loup can be removed with a proper instrument; another instrument, or strong iron bars, being introduced at B, to hold up the burthen while this is doing. The loup may be drawn into a bloom under a forge hammer, or passed through rollers. In either operation, it will, of course, be necessary to renew the heats, which may be done in a common chaffery, or in a heating furnace. This process is continued at the pleasure of the workmen, and as soon as a quantity sufficient for a loup accumulates, it is withdrawn, as above described. In the early stage of the operation, it will be necessary to charge the furnace, nearly, or quite to the top; but as the heat increases, the height of the coal may be gradually diminished; and at a very high temperature, from two to three feet of coal will be found sufficient. The cinder produced in this way will bear working a second time; an appropriate flue facilitates the operation, and as it is first fused, and sinks, and is thus interposed between the iron at the bottom of the hearth, and the coal, it contributes to prevent a mixture of the two. Holes may or may not be left in the sides of the furnace for the introduction of bars

to aid in detaching the iron from the bottom and sides; but this will often be necessary, if the back of the furnace be thrown sufficiently forward, and a proper direction be given to the blast; for which purpose, tuyeres are placed in different positions on three sides of the furnace, and at different elevations. One or two pipes may be used at pleasure. From the foregoing, it must be obvious that by the rapidity of the process, the saving thereby of time and labour, the substitution of a cheaper, more powerful, and abundant fuel for that now in use, and which is so made applicable to this object by the peculiar construction of this furnace,—a great and important improvement has been effected in the conversion of iron ore into malleable iron. The following drawings, *Figs.* 1, 2, 3, represent an elevation, and vertical and horizontal sections, all drawn to a scale of one inch to three feet, the same letters referring to corresponding parts of each. A is the tunnel head, where the furnace is charged;

Fig. 1.



to be provided with a cover, which is placed on in the intervals of charging, when the coal is low. B a projecting, open, hollow hearth, for the reception of cinder and iron, with a cinder hole at C, to be opened when it is wished to draw off the cinder. D D are tuyeres for the introduction of the blast, placed in different positions on three sides of the furnace, and at different elevations, to vary the direction of the blast at different stages of the process. The back and front walls may both or either be thrown or inclined somewhat more inward than is represented in the drawing, and as indicated by the dotted line on the vertical section; and with advantage when the ore is not very pure, and makes much cinder. The furnace is to have over it a brick canopy or chimney, to aid in carrying off the gas given out by the coal. The furnace is lined with fire brick, and is cased with cast-iron plates, secured by strong bolts, keys, and screws, and between the casing and the lining,

Fig. 2.

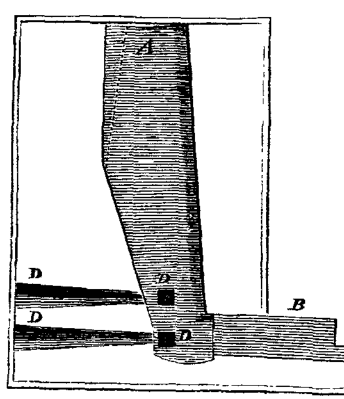
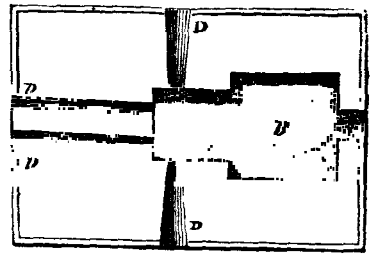


Fig. 3.



common brick, with a thin packing of sand; the latter, to prevent injury from expansion. In a letter to Dr. Jones, (the editor of the *Journal of the Franklin Institute*) Mr. Howell, the patentee of the furnace just described, states that he had completely succeeded in making bar iron, and even nails with it, without suffering the iron to cool; and that practical forgemen, who performed the manual labour, were astonished beyond measure at the result; the iron being as good as that made at the neighbouring forges in the old way.

Refining with Mineral Coal.—A patent recently granted in America, to Mr. C. Lewis, (of Pine Creek, Alleghany County, Pennsylvania,) for refining pig iron, seems also to be well deserving of the attention of the English manufacturer. The process is chiefly effected by mineral coal, uncoked, but in such a manner, that the metal while in a state of fusion is not brought into contact with the mineral coal. A reverberatory furnace is employed; the mineral coals are put on the grate-bars, and when the furnace has acquired a melting heat, a door at the side of the furnace is opened, through which a bushel of charcoal is introduced into a basin ten inches deep, previously covered with a stratum of silicious sand; over the charcoal is distributed, so as to cover it, a bushel of hammer or forge cinder, and then about a ton of pig metal, so laid around the basin as to leave a space between each pig; thereby a greater surface of the metal is exposed to the action of the flame. The fire in the grate is now to be well supplied, and maintained; and all access of air prevented, except through the grate. In about half an hour, the metal will be nearly melted, which, when the workman perceives to be the case, he drags, by means of an iron rabble passed through a hole in the door, the whole of the metal from the sides, into the basin. He then introduces from three quarters to one bushel of charcoal upon the surface of the metal in fusion. The fire being kept up, and the metal frequently stirred, it will, in half an hour after the whole is melted down, be sufficiently decarbonized to let it run out of the furnace. The consumption of mineral coal in this operation is from 15 to 18 bushels, and two of charcoal of wood, to each ton of metal; and the ton of metal is obtained from only 22 cwts. of pigs. Owing to the intense heat of the furnace, the volatile parts of the coal are consumed, or pass along the roof of the furnace into the flue, while the surface of the metal is protected by the charcoal and the scoriæ, which in all cases keep uppermost without incorporating with the metal. Refining after the above way will be of great advantage to forges that make their blooms by means of charcoal, as it will greatly facilitate the procedure, and lessen the quantity of charcoal used. The iron made in the manner described is said to be quite malleable, close in texture, and fibrous. It is worthy of observation, that this furnace requires no machinery attached to it, and the process appears calculated to effect some important savings to the manufacturer.

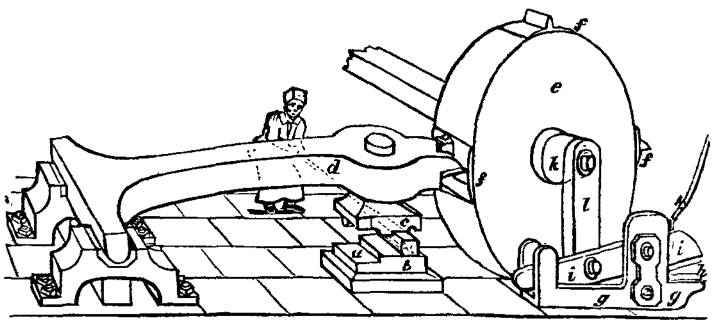
Salts employed in making Iron.—A patent was taken out a few years ago, by Mr. Luckcock, an iron master of Edgebaston, near Birmingham, for the application of the muriate of soda, (common salt,) to the iron in the puddling furnace just as the metal is breaking down into fusion; the action of which was said to be productive of that toughness and malleability which had previously been only effected by laborious and expensive mechanical agency. The proportion of salt to the iron was about two per cent. by weight. How far experience has proved the advantage of this mode of seasoning the puddlers' balls, we are not informed; but it might be presumed to have been successful, from its having excited the rivalry of others, who have since taken out patents for salting iron; amongst these we may particularly notice Mr. Josias Lambert, of Liverpool Street, London, who appears to have availed himself of some hints

out of an old fashioned receipt book. This gentleman adds (in his first patent, 1829,) potash to Mr. Luckcock's soda, in the proportion of one part of the former to two of the latter; and of this mixture he administers 15 pounds to the ton of ore in the blast furnace; in the refining furnace 12½ lbs., and in the puddling furnace, 11 lbs. to the ton. Mr. Lambert, in the succeeding year, 1830, took out another patent, entitled "an improvement in the process of manufacturing iron," &c. This improvement consisted in the addition to the former mixture of *two parts of lime!* thus making it two parts of "salt," one part potash, and two parts lime. But notwithstanding this powerful and *novel* auxiliary, he does not diminish the quantity of the mixture, but nearly doubles it. After this explanation of the nature of these presumed discoveries, it will be unnecessary to enter more into detail, as respects the quantities of the fluxes to be used in the several successive processes of the iron manufacture. We should not indeed have noticed these two last patents at all, were it not from the circumstances that this species of iron cookery has been, and is probably, still conducted upon an extensive scale. Of the novelty of the scheme, every chemist must be aware, that all the substances mentioned have been unscrupulously used as convenient fluxes in the assay furnace for a century or more; and as respects the eligibility of their employment in the great laboratories of the present day, we have the scientific and practical authority of Mr. David Mushet, for observing that they are considered useless.

The Forge, Rolls, &c.—For the purpose of introducing some recent improvements connected with the previously described departments of the manufacture, we broke off our narration of the usual train of proceeding of an iron work at page 768, where we left the puddlers' balls in the furnace ready for subsequent operations. Hitherto, we may observe, imagination has had to picture to itself the intense action and changes that have been going forward, unseen, and unheard; but henceforward, to the completion of the wrought-iron bar, the rod, and the sheet, all is activity and motion. The departments where those articles are produced are contiguous and open to each other; they are termed the forge and the mill, and are more or less extensive, according with the magnitude of the iron work. The impression upon a spectator, to whom the scene is novel, is one of extreme interest, and one that he never forgets; he finds himself in the midst of machinery of a peculiar character, and of extraordinary magnitude, remarkable for its massiveness and its weight, and in its effects astonishing. In the mill, at regular intervals of about a minute, he sees the distant gloom dispelled by the rising of a furnace door, which opens to his view a chamber full of dazzling light before which stands an invulnerable workman, who pulls from the midst of it a lump of iron, blazing like a meteor, and dashes it upon the ground. Almost as quick as thought, and before the furnace door can be closed again, the ignited mass of metal is eagerly snatched up by another workman, with a pair of tongs, who instantly applies it to the largest grooves of a pair of solid cylindrical "rolls," which are revolving with great velocity, and with such immense force, that the mass of iron is, as it were, *shot* through the rolls, and is so far altered in its figure, by the compression, as to be doubled in its length. Notwithstanding the rapidity with which the iron moves by the revolution of the rolls, it is uniformly seized as it comes out by another workman, who, with his assistant, tosses it back over the top roll, where it is again taken by the first workman, and passed through the next pair of grooves, smaller than the former; it is again seized by the workman on the opposite side, and treated as before; and thus it travels backward and forward, spontaneously illuminating its path by bright scintillations, through half a dozen or more successive grooves; all the while lengthening itself, perfecting its shape, and improving its quality, till it arrives at the end of its journey in about a minute after starting from its fiery chamber. The spectator, who may have taken his stand at a convenient distance, and has scarcely been able to comprehend more than the *possibility* of what he has seen done, from the celerity of its execution, is probably obliged to move farther off by the scorching heat of the still bright red, long, finished bar which has reached him. This bar has,

however, not passed its last channel before the effulgent furnace again opens its mouth, and another bright mass of metal is ready to follow the first; and thus, bar after bar is made till the contents of that particular furnace are discharged. During this splendid operation, the spectator has perhaps scarcely looked around him; to see a fly wheel, of twenty feet in diameter, and of ten tons weight, cutting through the air at the rate of ninety revolutions per minute; (more than 60 miles per hour,) driving by means of a massive cog-wheel on its axis, numerous other wheels at different velocities, to communicate the requisite power and motion to various other mechanism contiguous and remote; to observe that through the medium of other gear of due proportions, the ponderous rolls are made to turn on their thick axes or "necks" twice as many times per minute as the great fly; to trace the cause of motion of the latter, through a stout pinion on its axis, driven by a great toothed wheel, which is turned by a crank attached to the lower extremity of the heavy vibratory connecting rod of a magnificent steam engine, which, in its own separate apartment or house, is quaffing its potent vapour in silence, and distributing its constantly renewed energies around to all that require it; not excepting the ponderous machine which we shall next describe, the effects of which are the reverse of those which are complained of in the trunkmaker's hammer.

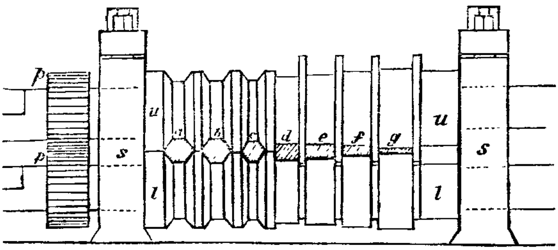
Shingling or Blooming.—The "underhand" having drawn a ball out of the furnace, his superior, the "shingler," takes it up by a pair of tongs and heaves it on to the depressed part *a* of an anvil *b*, which with its block (sunk in



the ground, and resting upon solid masonry) weighs several tons, at the same time another shingler, whose turn it is, (there being two shinglers to each hammer,) draws out of the furnace a stout flat bar, one of the two before mentioned, the end of which has been brought to a welding heat, and holding the cooled end wrapped round with a piece of nail bagging, he lays the heated end upon the ball under the hammer *c*, the first blow of the latter forces the bar into the ball flush with its surface, and they are thus instantly welded together, and form as it were, one piece; the bar thus becoming a long handle, by which the shingler can move and turn the ball about upon the anvil between every blow of the hammer. This hammer with its helve *d* weighs between four and five tons, and makes upon an average about 150 blows per minute; it is actuated by the revolution of a cylinder *e*, in the circumference of which are fixed, at equal distances, four or more wipers or coggs *f f* which successively come into contact with the underneath side of the extremity of the hammer helve, and thereby lift it up after each blow about 18 or 20 inches, whence it falls simply by its own weight; which operates so effectively as to reduce by a very few blows, the shapeless ball into a bloom. This bloom is a rough square bar, usually about 20 inches long, and 4 or 5 inches thick. By reference to the foregoing figure, it will be observed that the hammer head

has not an uniform flat face, but is of a varied form, and has several projections which answer to the rounded ends of common sledge and hand hammers, termed panes; by placing the bloom under these projections crossways, the bloom is extended lengthways; and by placing the bloom so that a pane shall strike it lengthways, its breadth is increased, and the grooves or dents which are thus made are worked out by bringing the bloom under the flat parts of the hammer. The effect of the hammering is not confined to giving it a new form, but a large quantity of dross is thereby worked out, and the sparks and scales fly off with great force, so that the workmen are obliged to be protected with thick leather aprons, leggings, &c. It sometimes happens, through mismanagement on the part of the puddler, that a ball has not sufficiently "come round to nature," and it shows its indisposition to submit to the gentle correction of the hammer by hissing and bubbling. This species of bloom is called a *shadrach*, and it is thrown back to the puddler, who has to pay a fine for having drawn it out of the furnace before it was sufficiently purged of its impurities.

Shingling Rolls.—In this early state of the manufacture of malleable iron, the office of the hammer just described is generally confined to giving the bloom only about fifteen or twenty blows, by which it is brought into a shape that will permit of its being, while still of a bright red heat, passed through the shingling rolls. The precise form of the grooves in these rolls is not material, and they differ in most works; the intention is to reduce the bloom as quickly as possible into a broad, flat bar, for a purpose that will presently be explained. In the annexed sketch, which we have made to illustrate the subject, two different kinds of grooves

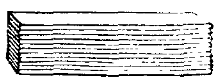


are introduced, both of which are employed. In the above figure, *u u* represent the upper roll; *l l* the lower; *s s* are the standards through which the necks of the rolls pass, and are therein made to revolve in opposite directions by the action of the pinions *p p* in gear with each other, to the shaft of one of which the power is applied; and by a continuance of such shafting, connected by clutch boxes, motion is sometimes imparted to a series of pairs of rolls, arranged in one line. In the preceding figure, the dark spaces between the rolls, respectively marked *a b c d e f g*, show the form given to the bars as they pass through those grooves. The bloom is supposed to be first put through *a*, and then through the others successively, until it is brought out at *g* in the form of a flat bar four or five inches broad, and half, or five-eighths of an inch thick. By the severe squeezing which the bar undergoes in passing through these rolls, an additional quantity of cinder or foreign matter is forced out of it; and it is worthy of remark that the grooves *a b c* powerfully contribute to this effect. The form of them is not designed to be an equilateral hexagon, but that of a square with the top and bottom corners taken off. In the horizontal line the angles are right angles, the bar will therefore in that direction be made wider than in its vertical breadth, where the angles are obtuse. Besides, there are usually between the rolls, where they are intended just to touch each other, little vacancies, into which the iron is compressed in its passage, and a burr is thus formed upon its angles; now, by turning the bar so as to present the right angles and burrs to the flat top and the flat bottom of the same, or the

next pair of grooves, they are thereby crushed down, and the dross is thus more efficiently worked out of the metal, and by the time it arrives at *g*, in the form of a flat bar, it is considerably improved in its toughness and malleability. Nevertheless, the iron is of an unmerchantable quality; it is still impure; is too easily broken; has a rough scaly surface, and its edges are imperfect.

Shearing the Bars.—This rough bar is therefore, immediately it has passed through the rolls, and while it is still red hot, put between the jaws of a pair of shears, worked by the engine, and cut into lengths of about a foot each. A pair of shears for this purpose is represented in the engraving of the great hammer at page 772, by reference to which the reader will readily comprehend our explanation of them. That portion of the shears marked *g g g*, is one massive casting, and is fixed to the ground in the most solid and substantial manner. The cutting edge of the lower chap at *h* is formed out of a stout steel bar; it lies in a rebate, and is therein fastened by screw bolts. The chap of the upper shear *i i* is similarly provided; this shear is the movable one, and has its joint or centre of motion in the upright at *g*. By the revolution of the drum *e*, it carries round with it an eccentric or solid crank *k*, to which is jointed a stout iron bar *l*, which bar being jointed at its other end to the upper shear, communicates its own vibratory motion to the shear, and makes it cut at each alternation of the stroke or revolution of the drum. To prevent the steel edges of the shears from being softened by the contact of the hot bars, a small stream of water is made to flow over them constantly, brought on by a small pipe, or other suitable channel, and regulated by a cock. The bars as they are cut, fall into an iron barrow or truck, in which they are wheeled away to the *piler*.

Piling.—The piler *piles* the pieces of the rough bar together in the manner shown in the annexed cut, putting as many upon one another as will form a bloom or a finished bar of the size and weight required. The piles are then taken or deposited in a convenient situation for being put into—



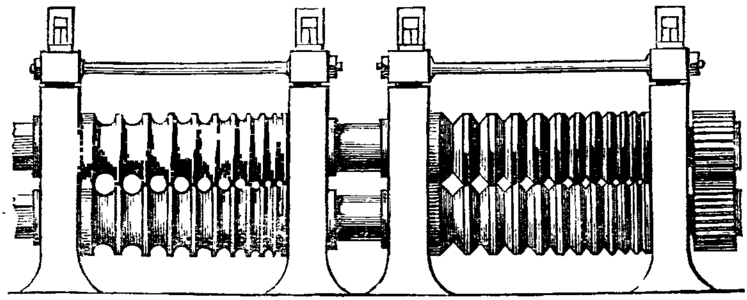
The balling or reheating Furnace.—This furnace is in no essential respect different from the puddling furnace already described; but the men who work them are usually called "ballers."

Balling.—With an iron instrument of the shape of a baker's peel, the baller places each pile on the bed of sand prepared to receive them, taking care not to disturb them, so as to cause any of the pieces to project beyond the rest, as these projecting pieces would, in consequence, be sooner heated, and sustain a severer action of the fire than the others, causing those exposed parts to burn or waste, and the whole mass to be deteriorated in tenacity. The number of piles put into the furnace is regulated by their size, in order that when they are sufficiently heated they may be quickly discharged; and as large heavy bars take longer to roll than small light ones, a less number of large piles are put into a furnace in making large bars, than of small piles in making small bars. Notwithstanding the baller arranges his batch so that the piles may be completely heated in succession, he exercises his judgment upon them with his eagle-like eyes, as to which bloom is in the most forward state. The ballers' proceedings are likewise regulated by the state of the other balling furnaces of the work, whose products are successively worked off. If a baller keeps his iron too long in the furnace, it is thereby rapidly wasted and deteriorated; on the other hand, he must be ready to a minute, that the rolls may be constantly at work, and that the power of the engine may not be wasted. The blooms that are now taken out of these reheating furnaces, are presumed to be of a quality adapted to the manufacture of common bar-iron, of which there is a very extensive variety of forms; but the great bulk consists of three kinds, namely, *flat*, *square*, and *round*, the latter being usually termed bolts. Of the three last-mentioned classes, there are very numerous sizes, as will be seen on reference to the tables subjoined to this article.

Variety of Rolling Apparatus.—For the manufacture of so extensive a variety, a great number of rolls is required in an iron work. The stock of these

ponderous tools, in some works, consists of upwards of a hundred pairs; and there are commonly from ten to twenty pair of standards (fixed in the most firm and solid manner that art is capable of) ready for their reception. A sufficient example of this kind of mechanism for making *flat* bars has already been given at *d e f g*, in the cut at page 773: in the illustration which follows, the rollers for making *round* and *square* bars are shown. These rolls are called *finishing* rolls, for the bar, previously to being brought to them, is passed through several grooves of a pair of *roughing* rolls, which are of greater diameter than the

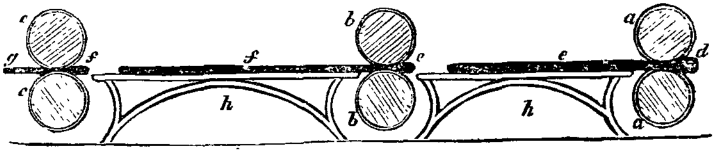
Fig. 3.



finishing rolls, and furnished with larger grooves. In these last-mentioned, the bars are reduced to nearly the intended size, and they are then run through two or three grooves of the finishing rolls; each time that a bar is passed through, whether round or square, it is turned a quarter round to take off the burr or fin, formed at the junction of the rollers, and through the last hole it is usually passed twice, by which its figure is perfected. The effect of the piling and reworking the iron, as just described, has been to weld the several layers of the pile together, which thus become one solid mass, possessing a fibrous texture and an increased toughness; and during the operation, many of the impurities that the iron had retained are expelled. In rolling flat bars, the treatment is different from that of square and round; the pile is never presented to the rolls with the edges of its layers upwards, but always with their flat sides horizontal; for were the bar rolled upon the edges of the layers, the welding would probably be very imperfect, and the bar comparatively weak. Each bar after it is completed in the rolls, is taken by two boys with tongs, who first put the marks on with steel punches; they then present its extremities, which are usually ragged and uneven, to be cut off by a pair of shears that are constantly opening and shutting by the action of the engine; the boys then take the bar, and lay it along a solid cast-iron bench, perfectly flat, and having a straight edge on one side; and as the bar is still hot, they easily make it perfectly straight by a few blows with wooden mallets.

Process of Rolling—Defects and Improvements.—To give the reader a clear insight into the mode of working a bar through the rolls, it appears to be necessary partly to repeat what has been before but imperfectly noticed. A bar of iron, as it passes through each successive groove of a pair of rolls, is received on the opposite side by two men, one of whom draws it out by the end with a pair of tongs, and the other supports it by a lever to prevent its making too sudden a bend; and when the bar is through, these men pitch it back again over the top roll for it to pass through the next groove; and this operation is repeated until the bar is reduced to the required size. Now it must be evident upon reflection, that this returning of the bar over the rolls occupies about as much *time* as the actual rolling; consequently that the iron becomes cooled in proportion, harder, and requires more power to roll it; that the workmen have a very severe labour to perform, and are all the while exposed to a scorching heat. These defects in the ordinary process of rolling forcibly struck the writer

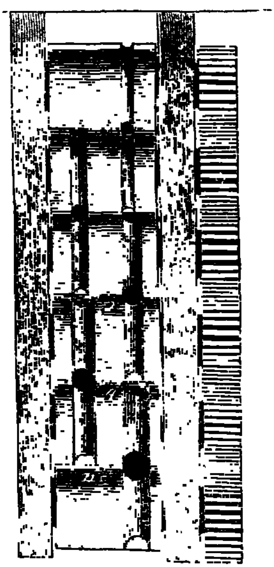
several years ago, when he proposed two methods of continuous rolling, by which it was estimated that the manual labour would be greatly reduced, the personal inconvenience diminished, the cost of the machinery lessened, and one-half of the power of the engine saved. The first of these plans was to place a series of pairs of *small* rollers (that is, short in their axes) one before the other, so that the bar might pass in one continued straight line, from groove to groove, until finished of its intended dimensions. This plan is explained by the annexed diagram; *a a*, *b b*, and *c c*, represent the transverse sections of



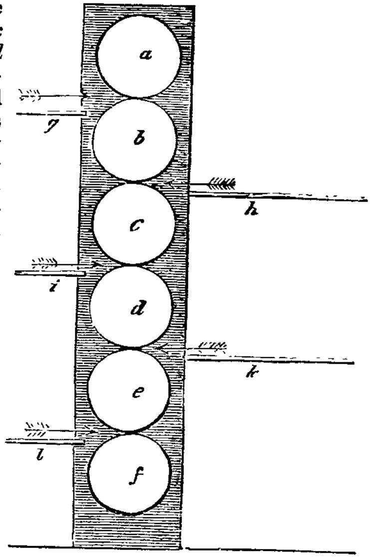
three pair of rollers, with grooves of different depths; the bar is supposed to enter at *d*, and by passing through the rollers *a a* to be reduced to the size *e*, where the bar slides upon a form *h*, guided thereon in a straight line by a furrow of the shape of the bar, direct into the grooves of the rollers *b b;* the bar of the size of *e* is here reduced to that of *f*, lying on another form *h*, which conducts it through the rollers *e e*, and is thereby further reduced to the size of *g*, or any other that may be required by a suitable extension of the apparatus. By this method it was considered that a bar would be rolled in about one-third the usual time; that the manual labour would be reduced to a trifling amount; and that not one-half the usual power required of the engine would be absorbed. The latter advantage results from the celerity of the operation; for as the iron is much hotter, it is much softer, and requires a less amount of force, even during the diminished time taken up by the process; but the most important advantage is, that a *better* bar is thereby made; when the maxim to "strike the iron while it is hot," has thus been duly attended to, the bar, instead of being cracked at its edges or otherwise unsound from being rolled when too cold, will be uniformly solid and of a more perfect form.

The second plan devised was to put a series of small rollers one above another, with the usual spur gear on their axes, which would give every succeeding roller an opposite rotation, so that the bar might enter between the first and second roller, go back through the second and third roller, then through the third and fourth, the fourth and fifth, and so on to completion. In the annexed, *Fig.* 2 affords a side elevation, and *Fig.* 3, on the following page, a vertical section of six small rolls, *a b c d e f*, which, by their arrangement, are in effect five pairs. In *Fig.* 3 the letters *g h i k l*, show the situation of five shelves, (the proportionate length of which cannot be shown,) on which the iron slides; and the arrows in the same figure indicate the course taken by the bar through all the rolls. The shelf *g* is supposed to be upon a level or somewhat lower than the mouth of the furnace, the bloom from which is to be slided down upon *g*, and pushed between the rollers *a* and *b*, and as it passes out of these, it gradually bends down,

Fig. 2.



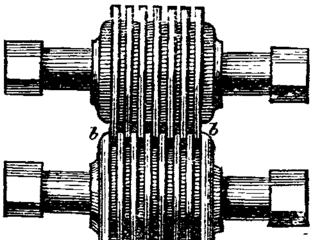
the end falling in the position of the arrow at *h*, ready to enter between the rollers *b* and *c*; then upon *i* between *c* and *d*, upon *k* between *d* and *e*, upon *l* between *e* and *f*, and so on to any number of rolls underneath, or be conducted forward to another series of rollers placed before it. Both the plans now described may be employed separately or jointly; but for various reasons the vertical series would be preferable for roughing the work, while the horizontal arrangement would probably be best suited for finishing the work. It is to be understood that the foregoing diagrams are only designed as explanatory of the principle of construction, all the subordinate details being omitted as unnecessary in this place. Previous to the year 1828, the writer had never seen nor heard of iron being rolled on either of the plans described; he had seen several iron works, one newly built, in none of which, however, was the principle adopted; he could find no published account of any thing of the kind; his mechanical friends said the plans were new and valuable, and a patent was determined upon if the opinions of two or three respectable iron masters, whom he consulted, should be favourable; when, singular to relate, two of these persons, who had very extensive concerns, condemned the plans as useless and impracticable, while the third said they were not only practicable, but highly advantageous; and he proved the truth of his assertions by showing the writer his works, wherein iron was at that time being rolled on the very principle of both plans, where he was informed it had been practised for several years; and that similar rolls were used in several of the works of Staffordshire! This fact has been mentioned with the view of inculcating circumspection in inventors before they incur the expense of patents, and a disregard of dogmatical opinions when unsupported by reason. It is worthy of remark in this place, that in none of the recent treatises on the iron manufacture has any notice been taken of this important improvement in rolling iron. The plan at the iron works where the writer saw the principle in operation, is a modification of that which has been described; it consists of only *three* rolls one above another, but of the same kind as those delineated at page 775, so that a bar which has passed through a groove between the top and middle roll is sent back through another groove between the middle and lowest roll; and there being many grooves in each of the three rolls, they are thus passed alternately through the upper and lower range of grooves until completed: but in making vat hoops, the bar, after being passed through several grooves, to roll it to a thin, yet rough flat bar, proceeded onward horizontally (in the same manner as shown in the diagram, page 776), and entered between a pair of plain polished rolls, where it was reduced to the required thinness, and a smooth face was given to it.



Horton's mode of rolling large Bars.—For bars of still greater dimensions Mr. Horton adopted the following process, for which he took out a patent a few years back. Instead of rolling the single blooms, and then welding the bars together, to get bars of the sizes required, he takes the blooms ("billets," he calls them,) from the puddling furnace, welds several of them together under the great hammer, then submits the united mass to the operation of the rolls. Great bars, thus prepared are said to possess a more laminated and fibrous texture longitudinally, than those which are united by welding together ready formed bars.

The various Forms of rolled Iron.—Having seen that round iron is produced by the junction of two semicircular grooves in the opposite rollers, the reader will readily perceive, without the aid of a figure, that "half-round iron," (that is, semicircular in its transverse section,) will be produced by having only one roller with a semicircular groove, and the opposite roller with no groove at all; and that, by making the groove of less depth, that is, of an elliptical curve, a semi-elliptical, or "half-oval" iron bar will be formed; also that by the junction of two semi-elliptical grooves, "oval iron" will be the result. The two last-mentioned sorts are extensively used by coach smiths; also for the tops of fenders, wire-guards, and such like. It will likewise be evident to the reader, that as square iron is made by two angular grooves, one of such grooves opposed to a plain roller will produce triangular, or "three-square iron;" that as flat bars are made by grooves of this form ▬, it will be only necessary to make the opposite groove deep and narrow, thus ▮, and let the latter groove come next to one end of the former, to produce L or "angle-iron." This angle-iron, though of recent introduction, is, on account of its very great utility in making framing, cases, boilers, and a thousand other things, a great favourite with all kinds of smiths, as it enables them to execute superior work with much less labour. Seeing how the angle-iron is made, it will be readily understood that, by placing this ▮ groove so as to come in the middle of this ▬ groove in the opposite roll, that "T iron" will thereby be rolled; and this brings us to a clear understanding how "railway-iron" is made, as the form is usually but a slight modification of the T, by a little rounding of some of the parts; and by obvious combinations of the foregoing, it will be seen how "iron mouldings," of an infinite variety, may be produced by a pair of rolls, and with far more facility and dispatch than a joiner can make them of wood with his moulding planes.

Slit Rods.—The manufacture of this article is interesting from the wonderful rapidity of its execution; and that it is of great importance in its results, it need only be stated that in the neighbourhood of Birmingham alone, it furnishes the highly-convenient raw material to upwards of sixty thousand people, men, women, and children, who are employed in nail-making, besides being applied to an infinite variety of other purposes. The slitting is performed by what we would define to be a series of circular shears, formed by the continued contact of a pair of deeply-grooved steeled rollers, which cut by the intersection of their angular edges, as will be clearly understood by reference to the subjoined engraving, which exhibits a pair of slitting rolls, adapted to slit a flat bar or slab, of about seven inches wide, into thirteen equal parts. An end view of this slab is intended to be represented at *a*, and by presenting it between the two rolls at *b b* it is obvious that the edges, as they intersect each other in their revolution, will divide the slab in the manner shown at *a*, and force them into the cavities between them, in which manner they will pass out of the rolls in a finished state, requiring only to be tied up into bundles afterwards, of the usual weight of 56 lbs. To facilitate the operation of slitting, the bar passes from the rolls where it has been formed of the required dimensions, in its red-hot state, directly between the slitters. In this manner upwards of thirty rods, of a small size, are made at once by a single revolution of a pair of rolls. As the sizes and forms of the rods required are extremely various, it is necessary in a slitting mill to have, at the least, two pair of rolls for each size, that a freshly-turned pair may be in readiness to supply the place of those which become worn or damaged. Slit rods are always more or less ragged at their edges, but this is of trifling import compared to the advantage of their great cheapness, especially in the making of nails, where they have to be drawn out under the hammer. To prevent any



considerable burr, or ruggedness of edge in the rods, the slitting rolls are turned with great care and truth, so as accurately to fit each other

Rolling of Plate or Sheet Iron is performed between perfectly plain rolls, as before mentioned, for hoops; but the rolls are necessarily of greater dimensions, frequently as wide as five feet; and of course a very great power is required to compress at once so extensive a line of surface. For ordinary sheet iron, such as is called " double and single plate," only one pair of rolls is employed at a time, the rolls being set nearer together by regulating screws, each succeeding time that a sheet is passed through. In rolling boiler plates, which are often more than half an inch in thickness, and weigh more than 2 cwt. each, the manual labour is very severe. The iron for these plates is prepared by making a pile of rough bars, which is heated in an air furnace, and then subjected to the action of the great forge hammer, already described, which reduces the pile to a thick slab, the forgers moving it under the hammer, so as to give it somewhat of the figure, as to length and breadth, required for the finished boiler plate. It is then heated again in the furnace, and rolled to the required thickness by repeatedly passing the plate between the rolls, the rollers adjusting the rolls nearer together each succeeding time, and taking due care to present the plate in such positions as will extend it to the required shape and dimensions, sometimes making it enter the rolls corner ways, sometimes lengthways, and sometimes breadth ways; the skill and efforts of the workman being directed to bringing the plate to the required form and dimensions at one heat, and so as to require but very little superfluous edging to be subsequently taken off by the shears.

Rolling Rods.—Round rods, and those of a square or flat shape, that are required more perfect in their figure, and with a smoother surface than those which are split by the process described, are made by rolling with small rolls that are case-hardened, and have their grooves very nicely formed. They are usually from six to seven inches in diameter, and make from 230 to 260 revolutions per minute, and the rods, whilst between the rolls, are drawn through them at the same velocity. They are rolled of great lengths, sometimes upwards of forty feet, and are afterwards cut to the required lengths, and tied into bundles of 56 lbs. each. Round rods are thus rolled so small (about three-sixteenths of an inch), as to form a very useful and cheap substitute for wire. It is extensively used by wire-workers, and in making "invisible fences;" also by tinmen, coppersmiths, and other trades; but especially in those cases where it is covered over, and employed to stiffen flexible substances.

Red-Short, is a term given to bar iron that has the defect of cracking or breaking, when punched or bent, while at a red heat. It is generally very strong when cold, and therefore useful in that state; and when it is worked, care should be taken by the smith not to subject it to severe strains at that peculiar heat in which it is disposed to give way.

Cold-Short, is that kind of iron that readily breaks when cold, but is easily wrought under the hammer when heated.

Testing the Quality of Iron is usually performed by cutting a nick on one side of it with a cold chisel, then bending it down, or giving it a blow with a sledge hammer. If the iron be bad, or cold-short, it will break, and exhibit a resplendent, crystallized fracture; if, on the contrary, the uncut part bends back, and exhibits the appearance of a bundle of silky-looking fibres, such iron will probably stand the heated test of bending it double whilst at a cherry-red heat, first in the direction of the pile, and afterwards at right angles to it. If the iron does not crack by these tests, it is neither cold-short nor red-short, but of a tough good quality. We have now given a pretty general outline of the process of making *common* malleable iron, but there remains to be explained in what respect the processes differ in the preparation of the superior kinds.

Best Malleable Iron.—The correct meaning of the term " best " is very different to the signification of it in the iron trade, in which it now implies the next better quality than common; and it is usually said to be made by a repetition of the process at the balling furnace, the forge, and the rough rolls; that is to say, the rough bar of the common iron already described, is cut, piled,

and made into a bloom once more, which confers upon the metal a more fibrous texture, and considerably increases its toughness and elasticity. We believe, however, that much of the iron that is sold under this denomination undergoes a different process, which does not improve the quality to the same extent. We are informed that best iron is more commonly prepared from pig metal of a better quality, namely, the dark grey, whose fracture is brilliant, and of a silvery white colour. These are carefully refined and puddled, without any admixture of inferior materials; the bloom is well hammered, and when rolled out into rough bar, it is made thinner than for common iron; this is afterwards cut into short lengths, piled, reheated, and rolled out to the required size, as in common iron.

Scrap Iron.—There is another kind of best iron, distinguished by the name of "scrap-iron," being made up of all the *scraps*, short lengths, ends cut off the finished bars, as before explained, and all the little bits of wrought iron that can be collected together. Of these there is always a considerable quantity accumulating in an iron work; the larger pieces are made up into piles, and the smaller into balls. The piles may be heated to a welding heat, and rolled at once into finished bars, but the balls, consisting of smaller pieces, are shingled under the great hammer, to consolidate them and bring them into the form of a bloom. This bloom is reheated, and when rolled, produces excellent tough iron, superior to the piled scraps that have not been shingled. Scrap-iron, thus reworked, often produces so excellent a quality, as to fall under the denomination of the next described quality of iron, namely,

Best-best Iron, No. 3, Chain-cable Iron.—These names, and various others intended to denote the superlative degree, are given by manufacturers to that kind of iron which is deemed to be, in reality, of the best quality, prepared with mineral coal. This metal is chiefly manufactured for the purpose of enabling it to resist most effectually a longitudinal strain or tension; and the property is best acquired by the careful selection of the best materials, and repeatedly cutting, piling, shingling, and rolling, as before explained. In the preparation of this superlative quality of iron, the utmost attention to the process is necessary; and any bloom or bar that may be incidentally injured in its tenacity should be rejected by the manufacturer, whose reputation might be injured by such iron receiving the mark that properly belongs only to the primest quality. It is this kind of iron which is chiefly employed in the making of chain-cables, in tie-rods and bolts, that are subjected to a powerful strain.

Charcoal Iron.—This term is originally applied to such iron only as had been prepared solely with wood charcoal, from the ore to the malleable and finished state; but now the name of charcoal iron is given to malleable iron, the ore of which may have been smelted with coke, in the ordinary blast furnace; and it acquires its distinguishing name from the circumstance of its being *refined* with wood charcoal. The process of refining, and also that of puddling, are performed as one in a puddling furnace, wherein it "comes round to nature," combined with less impurities than by the common mode described. The bloom, when taken out of the furnace, is put under the heavy hammer, and brought to the form of a flat cake, when intended for sheet iron, in which state it is denominated stamped iron. The stamped iron is next broken into pieces, piled, heated, and again put under the hammer, which reduces it to a slab of about one hundred-weight. These slabs are used for a variety of purposes; but their chief application is by the manufacturers of tinned plates, who reduce the "charcoal slabs" to the required thinness preparatory to the tinning operation. (See Tinning.) When the charcoal iron is required for bars, it is treated in all respects in the same manner as in making of the very best chain-cable iron. Owing to the large quantity and expensive nature of the fuel employed, charcoal iron is much dearer than coke iron; yet, from its great toughness and uniformity of texture, it is always preferred by engineers in the fabrication of steam-engine boilers, and, generally speaking, for all the important parts of machinery that are liable to severe tension.

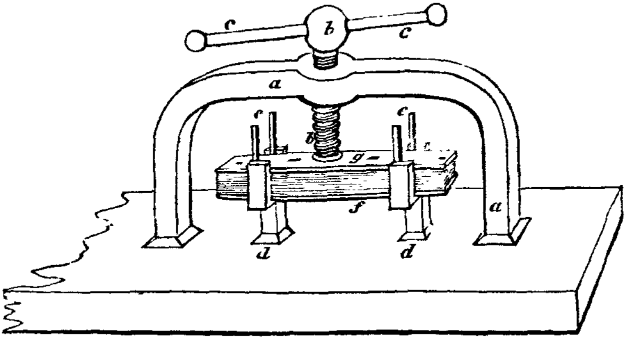
Re-manufactured Iron.—Worn-out and broken articles of iron, termed old iron, are collected throughout the country, and purchased by a class of tradesmen

called dealers in marine stores, who sort them into three kinds for sale. The first is called "coach-tire," and consists of the old wheel tire of carriages, and other large pieces; the second is called "nut, or scrap iron," and consists of nuts, nails, screws, holdfasts, hinges, and an infinite variety of little solid pieces; the third is called "bushel iron," and consists chiefly of very thin articles of iron, such as those which have been of rolled sheets or hoops. The last-mentioned is of the least value, on account of the great waste by oxidation, and the trouble attending it. The iron so collected and separated by the dealers is so considerable in and near London, that although a large portion of it is sent by the Grand Junction Canal to the works in Staffordshire, and another large portion of it is shipped on board the coal ships, in lieu of ballast, for the Newcastle works, still there is a sufficient supply for three iron works near the metropolis; namely, one at Wandsworth, another at Chelsea, and a third at Rotherhithe. The last-mentioned, called the King and Queen iron works, is a very old establishment, and the most considerable of the metropolitan works, the quantity of hoops and bars made there being from fifty to a hundred tons weekly: the quality, also, of the iron manufactured at this work (well known in the trade as King and Queen iron) is justly celebrated, which may be accounted for by these circumstances—nothing but old iron being used, the machinery being of the most improved kind, and a vigilant attention to the essential parts of the process. By the liberality of the proprietor, Mr. Howard, we have had an opportunity of inspecting this work, of which we shall give such a brief notice as will enable us thereby to complete our account of the manufacture of English malleable iron.

A number of poor women are employed in piling up the scrap-iron into balls, as they are called; but the form is that of a short cylinder, resembling in size and figure the crown of a man's hat, somewhat narrower at the top than at the bottom. A flat circular piece of sheet iron forms the foundation, and on that is raised the fabric, the larger pieces on the outside, the smaller in the inside, to fill up the interstices, and the whole as solid and compact as can readily be done. Care is especially taken not to put any little bits of brass or copper that may be accidentally mixed with the iron into the piles, which would prevent the consolidation or welding of the mass; and, to encourage the vigilance of the pilers, they are allowed the copper and brass they may thus find as perquisites. The balls are put into a reverberatory furnace, similar to the puddling furnace we have described: when brought to the proper welding heat, they are subjected to compression by a "squeezer;" this is necessarily a very strong machine; it is composed of a fixed lower jaw, of great massiveness and breadth (about a foot of superficies) on which the ball is laid, and is operated upon by the motion and force of the upper jaw, which, being actuated by the engine, is continually opening and shutting during the process, and thus it chews, as it were, by half a dozen or a dozen bites, the great ball of iron into a suitable shape to be passed between the shingling rolls, whereby it is, in a few seconds, reduced to a short, very thick bar or bloom. This bloom is re-heated in an air furnace, and then it is reduced between the rollers to a bar, a plate, or a hoop, equal in quality to the "best iron" from pigs; but it is, nevertheless, the commonest iron made in this re-manufacturing process.

We have now to explain the mode of preparing the larger pieces of old iron before-mentioned for re-manufacture. A number of men and boys are employed in clipping, with large fixed hand shears, the old hoops into convenient lengths, and other old articles into suitable sizes, to be afterwards made up into bundles, called faggots. The wheel tire, which requires great force to cut through, is effected with a pair of shears worked by the steam-engine: the materials, as they are cut, fall into barrows, in which they are conveyed to the faggotting department, where several men are employed in preparing the faggots at a stout bench, on which are fixed convenient little machines, for facilitating the operation. One of these is represented at page 782. *a a* is a stout bridge-piece, in the centre of which works the screw *b*, by turning the handles *c c*; *d d* are two forked bearers, in which are laid two soft iron bands *e e*, bended to fit the square to the bottom of the bearers. On these bands is first laid a piece of wheel-tire *f*; on

this tire, pieces of hoop and other thin stuff are then evenly laid, which last are covered with another piece of tire *g*. Their crooked or curved forms prevent their laying so close together as is desirable; the turning of the screw, however, forces them together very compactly, as shown in the sketch. Thus held down



by the screw, the bands *e e* are brought together and twisted, which holds them fast, and the faggot is completed. The screw is turned back, the faggot taken out, and others are made in like manner. The sizes of the faggots vary much, being proportioned to the size of the bar, or other article to be made of it. If not more than twenty or thirty pounds each, as required for making puncheon, butt, or vat hoops, or small bars, they are, after being duly heated in the furnace, at once rolled out into their intended dimensions. If the faggots are large, they are heated and shingled into blooms, which are again heated when required to be rolled out. It is the practice at these works, as well as others, to prepare large quantities of blooms, to be kept as stock; but there is a great economy in finishing the work by the first heat of the faggot, and this is facilitated by the quickness at which the rolls travel in making the lighter articles above-mentioned; and when, as at these works, the rolling is effected by *three* rollers, one above another, by which the iron is rolled both backwards and forwards (as before explained), a very long bar or hoop is completed in little more than half a minute, and, consequently, while the iron retains a good heat.

The first quality, or best king and queen iron, is thus prepared:—a ball or faggot, being duly heated, is first compressed a little by the squeezer, then rolled to a flat bar in the shingling rolls; the bar is next cut into pieces, piled, re-heated, and made into a *best* bloom under the shingling hammer. This best bloom is next re-heated, passed through the roughing rolls, and then through the finishing rolls, whereby it is brought to the form required. It is an important consideration, that much of the old iron used in the re-manufacturing process was originally the "best" iron of the first manufacturer; and that as the greater part of the old iron has been *improved* at the blacksmith's forge, it may safely be said, that where the processes of refinement of the first manufacturer leave off, those of the re-manufacturer begin: and as it is universally admitted that the more iron is worked, the better it becomes, (which is indeed proved by the extreme tenacity of fine iron wire,) it seems to follow, that the re-manufactured iron we have been describing must be greatly superior to that which is newly made from pigs, however carefully the process may have been conducted, or however often it may have been repeated.

Russian and Swedish Irons, which were formerly usually employed in our iron manufactures, are still applied extensively at Sheffield and some other places, in the fabrication of the superior kinds of steel and fine cutting instruments; but their application to other purposes is extremely limited, on account of their much

greater cost than our own best charcoal iron, which is scarcely inferior for most purposes to which bar iron is applied. The Russian and Swedish irons are entirely converted and refined with charcoal by processes so similar to our own as not to need description. These valuable foreign irons are more particularly noticed under the sub-head *Steel* in this article.

Malleable Cast-iron. A very extensive manufacture of iron articles is now carried on at Birmingham, Sheffield, and other places, which although they are cast from fluid metal, are nevertheless malleable. This property is derived from two causes; first, the pigs are prepared from the rich and pure iron ores of Cumberland; and the metal thus obtained is combined with but a small quantity of carbon, so as nearly to resemble steel in colour, hardness, and the brilliancy of its fracture; and it has in consequence been designated by some manufacturers, *run steel.* An infinite variety of articles, including nails, saddlers' ironmongery, (and particularly such goods as afterwards receive another metallic coat, as those which are plated upon *steel,*) are cast from this metal. The castings thus produced are exceedingly brittle; but this property is entirely destroyed by a process termed annealing, in which the metal is deprived of the carbon to which its previous fusibility was owing, and is in consequence brought to that state of wrought iron requiring only the operations of the shingling forge and rollers to give it a laminated and fibrous texture. Nails made by this process may be drawn out longer, and bent backwards and forwards, without breaking. The metal is however not so strong or tough as hammered and rolled iron; the discovery of the process is nevertheless of great value, as many excellent articles are produced in consequence, which would not without it be made at double the cost. The discoverer of this mode of converting cast-iron goods into malleable, was Mr. Samuel Lucas, of Sheffield, who took out a patent for it in 1804; the specification of which we shall annex, as there are some manufacturers who, while they avail themselves of Lucas's process, assume it to be their own discovery, in consequence of making some unimportant variations. "I declare that my said invention of separating the impurities from crude or cast-iron without fusing or melting it, and of rendering the same malleable and proper for the several purposes for which forged or rolled iron was used, and also, by the same method, of improving articles manufactured of cast-iron, and thereby rendering cast or crude iron applicable to a variety of new and useful purposes, is thus to be performed:—the pig, or cast-iron, being first made or cast into such form as may be most convenient for the purpose intended, it is to be put into a steel-converting, or other proper furnace, together with a suitable quantity of iron stone, iron ore, some of the metallic oxides, lime, or any combination of these, (previously reduced to powder, or into small pieces,) or with any other substance capable of combining with, or absorbing the carbon of crude iron. A degree of heat is then to be applied, so intense as to effect an union of the carbon of the cast-iron with the substance made use of, and continued so long a time as shall be found necessary to make the cast-iron either partially or perfectly malleable, according to the purposes for which it may be wanted. If it be intended to make the iron perfectly malleable, from one half to two-thirds of its weight of iron stone, iron ore, or other substance, will be found necessary; if only partially so, a much less quantity will be sufficient. Five or six days and nights will in general be found sufficient, during which to continue the heat, which towards the close of the process cannot be too great. Care should be taken that the pieces of cast-iron be not of too great thickness, as it would have the effect of lengthening the process. But the proportion of the several substances made use of, and the degree and duration of the heat to be applied, must greatly depend, not only on the nature of those substances, but also on the nature and quality of the pig or cast iron employed, a knowledge of which can be obtained only by experience. *The cast-iron to be rendered malleable, and the substances to be made use of for that purpose, may be placed in the furnace in alternate layers; and in order to prevent the iron stone, or iron ore from adhering to the iron, a thin layer of sand may be placed between them. For the improvement of articles manufactured of cast-iron, the same directions may be observed; except that when the*

articles are small, a less proportion of the substances for producing malleability will be required, and also a less degree and continuation of the heat."

Steel. We place this well known invaluable substance under the head of iron, in preference to its own initial letter, considering that we may, with far more propriety, class it under that denomination than *cast-iron;* for the latter, which every body maintains to be iron, contains more foreign matter than steel, and of the very same kind; cast-iron containing about 7 per cent. of carbon or other matter, and steel considerably less than one per cent.; even so little in some specimens, as a four-hundredth part. Steel is besides so much like malleable iron, in density and hardness, that few persons, comparatively speaking, know how to distinguish one from the other. The difference between common steel and common cast-iron we understand to be this; that steel is a very compact and nearly pure iron, rendered more dense and hard by an intimate combination with a minute portion of carbon, with which in some specimens is found manganese and silex; and that cast-iron is a less dense and very impure iron, combined in an almost granulated state with a large proportion of carbon and other matters. We are supported in this view of the subject by the fact that in the manufacture of steel with bar iron and charcoal, by the process called cementation, the iron is increased in its specific gravity; but if the process of cementation be continued beyond the proper limits, the iron will absorb more and more carbon, until it becomes disintegrated, and runs down into cast-iron, the loose texture of which is indicated by its greatly reduced specific gravity.

The specific gravity of steel is	7.827
„ malleable iron is .	7.788
„ cast-iron is . . .	7.207

Now white cast-iron contains much less carbon than black cast-iron, and in consequence approximates more to the nature of steel. But white pig metal, obtained from the generality of British ores, and smelted with coke, contains so much impurity, that our manufacturers, rather than make steel direct, by abstracting the principal portion of the carbon from the pig, prefer purging the latter entirely of its carbon and other matters, by the expulsion of which it is converted into malleable iron, (as already fully explained in the iron manufactures;) and then giving the malleable iron that small dose of carbon by which it is made into steel.

Natural Steel.—In those countries where iron ores are found extremely rich and pure, and their reduction is effected by charcoal, excellent steel is produced from cast-iron, without an intermediate process; and this kind of steel has in consequence received the distinguishing name of Natural Steel. Formerly, this kind of steel was fabricated and chiefly used in this country, and it is still made in Styria and Catalonia, with great success. The French some time ago attempted the imitation, but notwithstanding some of their most scientific men were engaged in the undertaking, they failed in obtaining a natural steel equal to that which they imported from Germany. It had been previously asserted by Bergmann, that the natural steel of the Styrian and Nassau Liegen foundries, derived its excellence from containing a portion of manganese; and this opinion was subsequently corroborated by a writer in the *Annales de Chimie*, who had made some comparative analyses of the ores used in France and Germany. In support of his opinion, he mentions the fact that in the territories of Nassau Liegen, there are mines of manganese, and that the black oxide of that metal is employed as a flux in smelting iron intended for steel when their ores are found to be naturally deficient of that substance. This writer states, that steel in general, but particularly natural steel, is essentially an alloy of iron and manganese, combined with carbon, and that this alloy is the natural steel of Germany, generally in these proportions:—

Iron	96.84
Manganese	2.16
Carbon	1.00
	100.00

Hence he concludes that good natural steel ought to contain twice as much manganese as iron. Several years ago, the writer of this article (having a different object in view) mixed some black oxide of manganese with melted cast-iron, and the result was an exceedingly hard alloy, resembling steel. For obtaining natural steel, the ore is smelted, as for iron in blast furnaces; but the blast given is weaker, and is directed not upon the metal, but in a horizontal direction above it. The metal is kept covered with slag, and is not disturbed by stirring. When the iron is judged to be sufficiently refined, and has become nearly solid, it is taken out of the furnace and forged; after this, natural steel is withdrawn, there remains at the bottom of the furnace one or more pigs of cast-iron, rather hard, which are generally employed in fabricating implements of husbandry. The natural steel of Germany is extensively employed on the continent in the making of files, and various sorts of tools. The celebrated steel from Damascus, called damask steel, and that from Bombay, called Wootz, are both natural steels, being converted directly from the ore in crucibles. These "fancy steels," however, we shall take some further notice of, after having explained the more important operations of our manufacturers.

Blistered Steel.—The first process employed by our manufacturers in the preparation of steel is to stratify malleable bar iron with pounded charcoal in alternate layers, in a close furnace, to cause a gradual absorption of the carbon by the metal. In the engraving on p. 786, *Fig.* 1 represents a vertical section of the kind of furnace employed for this purpose; and *Fig.* 2 represents a plan of the interior structure, without the external conical walls which surround it. *a* and *b* are the troughs, called cementing pots, in which the bars of iron are laid to be converted into steel; the pots are made of a peculiar kind of fire-stone, not liable to crack or fuse; their dimensions are usually from 10 to 15 feet long, and from 24 to 30 inches in width and depth. The bars of iron, and the powdered charcoal are laid in the pots in alternate strata; the upper stratum of bars being covered with a thicker layer of charcoal than those underneath; above which is also laid a mixture of sand and clay, to prevent the charcoal from entering into combustion by access of the outward air. *c* is the external cone, of strong masonry or brickwork, of from 40 to 50 feet high. Inside this superstructure is a smaller conical dome *d*, called the vault, which is built substantially of fire-brick, or other material, capable of withstanding an intense heat. The vault rests upon external walls *e e*, at a distance from those which support the external cone, and the space between them is filled up with rubbish, sand, &c. The cementing pots *a* and *b* are supported upon a series of detached courses of fire-brick, leaving spaces or flues between them to conduct the flame under the pots. In the same manner the sides of the pots are supported from the vertical walls of the vault, and from each other by a few detached stones, so as to intercept the heat. The vault has a series of short chimneys to conduct the smoke into the great cone *c*, as shown at *f f*. In the front of the furnace, an aperture is made through the external building, and another corresponding in the walls of the vault; these openings form the door, at which a man enters the vault to put in or take out the iron; but when the furnace is lighted, these doors are closed by fire-bricks, luted with fire-clay. Each pot has also small openings at each end, through which the ends of two or three bars are left projecting in such a manner that, by only removing one loose brick from the external building, the bars can be drawn out without disturbing the process, to examine the progress of the conversion from time to time; these are called tap-holes, and should be placed in the centre of the pots to obtain a fair specimen of their product. The fire-grate is shown in *Fig.* 1 at *g*, consisting of bars laid over the ash-pit *h*, which must have a free communication with the open air. The attendant examines the state of the fire from the ash-pit *h*, which has steps leading down to it, and when he perceives any part of the fire not very bright or fierce, he thrusts a long hooked bar through the grating, and opens a passage for the air. The fire-place has no door, being built open at each end; but a quantity of coals is piled up before each aperture, so as to close the openings, and answer effectually the purposes of doors; from this heap of coals the workman shoves in, with a kind of long hoe, such quantity as may be required to replenish the furnace

from time to time, and the renewal of the coals to the heap prevents any air entering the furnace, but such as has passed upwards through the ignited fuel, and contributed to the combustion. The heat and flames from the fuel are reverberated by the dome *d*, and have passages underneath and around the pots. The degree of heat at which the carbon begins to be absorbed, is found to be about 70° of Wedgwood's pyrometer; this heat is kept up for about 7 or 8 days, according to the thickness of the bars, and the degree of carbonization required. When the process is completed, the furnace is suffered to

Fig. 1.

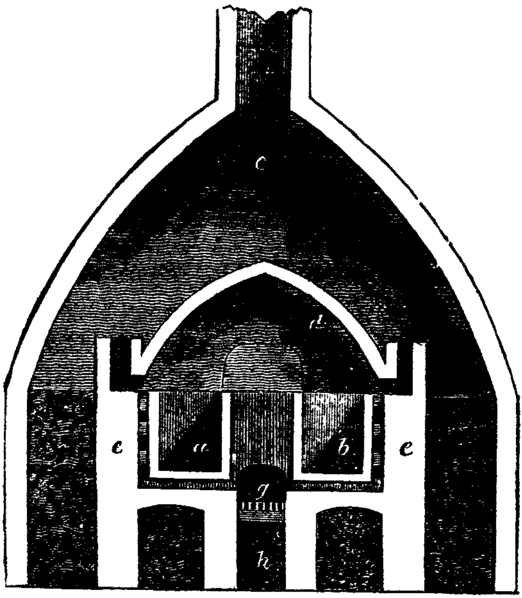
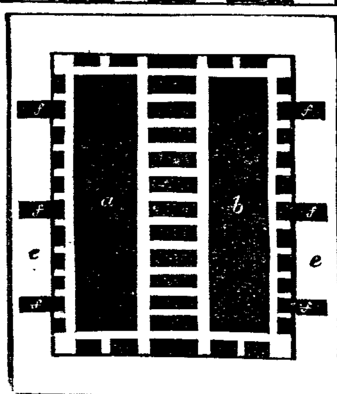


Fig. 2.



cool, which takes 6 or 7 days more; the contents of the pots are removed, and the fresh charges put in, the charcoal serving again, as it is scarcely altered from not having entered into combustion. The bars of iron are now found to be covered with blisters and projections, to have acquired a brittle quality, and to exhibit in the fracture a crystalline structure, which is uniform throughout the bar if the carbonization has been complete. The degree of carbonization is varied according to the purposes for which the steel is intended; and so

likewise is the nature and quality of the iron employed for the purpose. For the finest and most important purposes, the Russian and Swedish irons are always employed for conversion, by reputable manufacturers; and there are certain kinds, of long-established celebrity, to which a very general preference is given; these are distinguished by well-known marks stamped upon them, which the governments of the countries whence they are imported warrant the authenticity of. Amongst the chief of these marks may be particularly mentioned L inside a circle (called *hoop* L); G, with an L connected to the bottom of the G (called G L); two small circles (called *double bullet*); a G, and an F underneath, connected to it (called G F); an ellipsis, with some lines across its shortest diameter (called *gridiron*); J B, the J being made out of the upright line of the B (called J B); a stag's head and antlers (called *stein-buck*); a crown, with a C close underneath (called C *and crown*). Of course there are as many marks as there are manufactories or mines, many of which may furnish as good iron, but they are not yet so well established. There is, however, probably some exceptions to this remark, and undoubtedly the Russian iron, branded C CND D, is an exception. The hoop L, which is the produce of the Dannimora mines, in Sweden, is considered the most valuable; forty pounds sterling per ton being readily paid for it, which is about four times the price of the best English bar iron. However immense this difference of cost to the steel manufacturer, it is of trifling importance compared to that of maintaining his reputation for the production of an unexceptionable article. The paying of threepence per pound more for the raw material, will make no perceptible difference in the cost of the artist's graver, the surgeon's lancet, or even the writer's pen-knife—not to mention watch springs, and a thousand other applications of fine steel, in which, were it necessary to insure perfection of quality, a hundred times the cost of the raw material added to the manufactured article would be gladly paid.

Mackintosh's Patent.—A few years ago Mr. Mackintosh, of Crossbaskets, in Lanarkshire, took out a patent for converting malleable iron into steel, by subjecting it to a stream of carburetted hydrogen gas, evolved from coal under distillation. The iron is inclosed in a pot or crucible in the furnace, and when arrived at a proper heat, a stream of gas is directed by a pipe into the crucible, which has another aperture to allow that part of the gas to escape which has not been taken up by the metal. The apparatus for conducting this process will of course admit of various modifications. This invention appears to have reason for its basis; for it must be evident that in the process of cementation before described, the carbon must have entered into combination in a gaseous state with the iron: the steel made by it was reported to be excellent. Whether experience has proved it to be an economical process, is a point upon which we are not informed.

Mushat's Patent Steel.—The preceding articles are descriptive of three distinct modes of preparing steel. First, by the careful refinement of cast-iron; second, by the stratification of malleable iron with charcoal; and third, by the application of gaseous carbon to the metal. A fourth process, materially differing from those, but producing very similar results, and attended with some peculiar advantages, was patented in the year 1800 by Mr. Mushat, the gentleman whose metallurgical labours we have before noticed. The specification of the patent directs that *malleable iron* (in scraps or bars) is to be put into a crucible, together with a due proportion of powdered charcoal, or pit coal, plumbago, or any other substance containing the carbonaceous principle, and subjected to an intense heat in an air or blast furnace until the metal is reduced to a fluid state, when it is to be poured out into moulds to form ingots, or any other article that may be required; which castings will be of a similar nature to the steel produced by cementation. But in those cases when iron ore can be obtained sufficiently rich and free from foreign admixtures, the patentee proposes to save all the time and expense attending the tedious operations necessary for the conversion of such ore, first into cast-iron, and afterwards into bar iron; for such ore, he observes, being previously roasted or torrified, may be substituted for the malleable iron, and the result will be cast-steel, provided

the proper quantity of carbonaceous matter be used, as for the common and ordinary qualities of cast steel. The quantity of carbonaceous matter required, is much less than had been previously supposed to be necessary. In employing wood charcoal, from a seventieth to a ninetieth of the weight of the iron being sufficient; and when the quantity is increased beyond a seventieth to a sixtieth, or a fortieth of the weight of the iron, the steel becomes so fusible that it may be run into moulds of any shape, and afterwards be capable of being filed and polished. Hence, by casting, may be constructed stoves, grates, kitchen utensils, wheels, mill-work, and a great variety of things which could not be so made by the processes previously in use. By varying the proportions of the carbonaceous matter, he can make as great a variety in the qualities of the steel, as the various kinds of pig-metal differ from each other. Cast-steel, made in the ordinary way, Mr. Mushat observes, is so volatile when in fusion as not to admit of being run into any shape except straight moulds of considerable diameter; but that steel of such density as to admit of being cast into any form may be produced by his process, by increasing the quantity of charcoal, and fusing the matter as before directed. To produce qualities of steel softer than is usually manufactured by the common processes, he uses a very small proportion of charcoal, sometimes so little as a two-hundredth part of the weight of the iron; and he states that steel produced with any proportion of charcoal not exceeding the one-hundredth part, will generally be found to possess every property requisite to its being cast into those shapes which require great elasticity, strength, and solidity; and will also be generally found capable of sustaining a white heat, and of being welded together like malleable iron.

Tilted Steel.—As blistered steel in its crude state is applicable to but few purposes, it is moderately heated in a furnace, and subjected to the action of a tilt hammer, which strikes about 700 blows per minute: this operation increases its tenacity and solidity, and adapts it to numerous uses.

Shear Steel.—This name was given to a steel that was first made by Crowley, of Newcastle, about sixty years ago, in imitation of a peculiar kind of bar steel that we formerly imported from Germany. Crowley, however, stamped his production with the figure of a pair of shears, to indicate its suitable application. The process of making it at Sheffield, where the manufacture of this and all other kinds of British steel is conducted on an immense scale, is as follows:—The bars of blistered steel are broken into pieces of from one to two feet in length, which are then piled up into bundles or faggots of a size and weight adapted to their subsequent applications. The faggots are then taken up by means of a long bar having a ring at the end, into which one extremity of the faggot is inserted; and by means of the bar as a handle, a workman puts it into a reverberatory furnace, whence, after it is brought to a welding heat, it is taken out and placed under a heavy hammer, by which it is drawn out into a bar; this bar is then divided, the pieces laid together, brought again to a welding in the furnace, and then under the hammer, or by rolling, reduced to the size required. By this process the steel has lost much of its previous brittleness, and has acquired a uniform texture, which adapts it to the manufacture of a great variety of edge tools and other purposes to which it was before unsuited. Various qualities of shear steel are made, distinguished by the terms half-shear, single-shear, and double-shear, according to the number of times it has been cut, piled, welded, and drawn out.

Sanderson's Patent.—In September, 1828, a patent was taken out by Mr. Charles Sanderson, of the Park Gate Iron Works, entitled "A new process or method of making shear steel," which, the specification informs us, consists in forming shear steel out of very small pieces of bar steel, instead of pieces from one to two feet in length, as heretofore, whereby he is enabled to form shear steel with fewer heats, and consequently with less waste, and without the use of silicious sand, as heretofore practised. The patentee describes his mode of operation in the following words:—"I take bar steel in the state in which it comes from the converting furnace, and break it into very small pieces of one inch to two inches long; a quantity of these small pieces being ready, I procure a round stone of any quality which is capable of withstanding

the strong heat of a reverberatory furnace without cracking or breaking; and upon this stone the small pieces are piled as closely and compactly as possible; the whole is then inclosed in a fire-clay crucible, and placed in a reverberatory furnace, where it is allowed to remain until the whole mass becomes of a high welding heat. It is then taken from the crucible and placed under a heavy cast-iron hammer, usually called a metal helve, and exactly the same as those used in the manufacture of bar iron: this hammer is driven by machinery, and from the circumstance of the whole mass being in a semi-fluid state, it is almost instantaneously hammered or manufactured into one solid mass or bloom of steel, of from three to four inches square; this bloom is placed in a furnace, or as it is more generally termed, a hollow fire, of two or three feet square, heated with coke, and the heat increased by the application of a blast of air; and the whole mass or body of steel so hammered or manufactured as aforesaid, is raised to a high welding heat; it is then taken from the furnace, and placed under the same metal helve or hammer before mentioned, and drawn into a bar of shear steel, ready to be tilted or rolled into the various sizes or shapes which may be required. For shear steel, to be used for inferior purposes, it might be too expensive to place the piled steel in a crucible, but it might merely be placed in a reverberatory furnace, and drawn thence, when it is of a complete welding heat."

Cast Steel.—The finest and very best steel for most purposes, is that which has undergone the process of fusion and a subsequent hammering, called cast steel. It is about ninety years since this steel was introduced by one Huntsman, of Attercliffe, near Sheffield, whose name it continued to bear for a long time; but his rivals at Rotherham and Sheffield, who subsequently undertook the manufacture, gave it the more significant name which it now bears. The process of preparing it on the large scale, is as follows:—Blistered steel is broken into small pieces, and put without any admixture into crucibles that hold about 40 lbs. each, and are covered with a lid. The crucibles are separately deposited in a row of small melting furnaces, which are usually square pots, about 15 inches wide and 3 feet deep, with a grating at bottom; the tops of these furnaces are open, and level with the floor of the foundry; and just below their tops are lateral apertures or flues, leading into the common chimney of all the furnaces; access to the fire-places and ash-pits is had in a vault underneath. The fuel employed is hard coke, in which the crucibles are entirely imbedded and covered over; then each of the furnace mouths is stopped with a trap-door of fire-bricks, inclosed in an iron frame. This being done, a very sharp draught of air is produced from the ash-pits, through the fuel, into the lateral flues, and a very intense heat is produced, which, being kept up for four or five hours, the steel is thereby brought into perfect fusion, when it becomes necessary to remove the crucibles, and pour out their contents into cast-iron ingot moulds, prepared for their reception, which are either in the form of a short thick bar, for being tilted, or a thick flat cake, to be lamellated between the rolls. The melter has likewise to prepare himself against the terrible ordeal of the operation just mentioned: to protect himself from the fierce fire of the furnaces, as he bends over their mouths, which would otherwise set his clothes on fire, he puts on an armour of coarse sacking; and then, with a pair of long iron tongs, he gripes the blazing crucible, and, quickly lifting it out of its chamber, pours the contents into the moulds. The subsequent processes upon the ingots, bars, or plates of steel, cast in the moulds to bring them to the required shapes, are in every respect the same as we have described for preparing iron into similar forms; but on account of the greater value of steel, and the delicate manner in which it is often wrought, the rolling and hammering processes become more essential in perfecting the quality, and therefore they are more carefully performed. For the best purposes, steel is always preferred that has been drawn to its required sizes under a tilt hammer, which gives three or four hundred blows per minute. It is however deserving of remark, that when steel rods and bars have been repeatedly rolled at a low heat, they acquire the same density, and more uniformity, than tilted steel.

Needham's Patent.—A patent for a new process of casting steel was taken

out in 1824, by Mr. Needham, of Davis-street, Fitzroy-square. His plan is to employ large fixed or stationary crucibles (made of fire-stone, or Stourbridge clay), and allowing the steel, when melted, to flow from them, through suitable apertures made in the sides, into the moulds, instead of moving the melting-pots already described. The size and shape of these stationary crucibles, it is stated in the specification, may be varied according to circumstances, but a preference is given to an oblong form, with movable covers, fixed upon bearers of fire-brick or stone, on a plane a little inclined from the horizontal line; at the bottom of each crucible a perforation is made, to which is fixed a tube, that passes through the furnace to the moulds, with a plug at the external end; this being withdrawn, the fluid metal readily discharges itself into the moulds. In this manner several melting-pots may be fixed in one furnace, so that a quantity may be fused sufficient for articles of great magnitude; and as the different descriptions of steel require different degrees of heat for their fusion, the patentee recommends that those which require the least be placed in crucibles above those which require the most; by which arrangement, in casting large shafts or cylinders of steel, those parts that require it may be formed with the best steel, while those parts wherein an inferior steel answers the purpose, may, in like manner, be supplied with it. If it be required to cast a large cylindrical steel roller, the exterior may be made of a superior quality of steel, and the interior of a common quality, by placing a cylinder of wrought iron within the hollow cylindrical mould; and then directing jets of fluid steel, of distinct qualities, to flow into the opposite sides of this circular wrought-iron partition; the steel will then adhere to the iron, and form one solid roller, of inferior cost, but equal in quality to one made entirely of superior steel.

Thompson's Patent.—A short time after the granting of Mr. Needham's patent, Mr. Thompson, of the Chelsea-street Works, took out another, having a very similar object in view. He proposes, in the first place, to melt the steel in a reverberating or puddling furnace, by which pit-coal may be used instead of coke; secondly, instead of the movable crucibles in general use, he employs stationary vessels, made of the usual materials, but of a semi-cylindrical shape, having spherical ends, and a rebate or groove in the upper edges, to fit a cover to it. These are to be fixed on a slightly-inclined plane, for the convenience of the fluid discharging itself through a hole in the bottom, in which is inserted a tube of platina; this tube is connected to another tube of fire-clay, passing through the brick-work to the outside of the furnace, through which the metal flows into moulds, through apertures previously stopped with clay, which are tapped by means of a long rod tipped with platina.

Alloys of Steel.—Messrs. Farraday and Stodart, a few years since, made a series of experiments on the combinations of some other metals with steel, an account of which was published by them in the *Philosophical Transactions* for 1822; amongst the results of these experiments the following appear to be most worthy of notice. *Silver* can be alloyed with steel only to the extent of a five-hundredth part; when more was used, it either evaporated, or separated as the button cooled, or was forced out in forging. The alloy was said to be excellent; and the addition of price was no obstacle to its use for fine instruments. Steel, alloyed with one-hundredth part of platinum, though not so hard as the silver alloy, has more toughness; where tenacity as well as hardness is required, the extra cost was considered to be more than counterbalanced by its excellence. As far as the experimenters could judge, neither gold, tin, nor copper, improved steel. Messrs. Stodart and Farraday's memoir on this subject having been noticed in the public journals, some of our Sheffield manufacturers wisely considered that it afforded them a favourable opportunity to advertise themselves to the public, along with their wares made of "silver-steel;" and, for a while, knives and scissars, exquisitely finished, made of that "invaluable" alloy, were alone the fashion. Rival manufacturers sought in turn to amuse the public with *Wootz*, and *Damascus*, and *Peruvian* steel; and each of these were, for a time, necessary to the novelty-loving part of the public. Time had, however, swept nearly all the notices of these wonders of the day from our shop windows, and old-fashioned steel was quietly resuming its sway, when suddenly *meteor*

steel made its appearance, not from the clouds, nor the moon, nor from a volcano, but from the patent office, as will appear from the subjoined account of the enrolled specification.

Meteor Steel.—The patentees of this manufacture (Messrs. J. Martineau, jun. and W. H. Smith,) specify their object to be the preparation of an alloy of steel, having that peculiar wavy appearance exhibited in the Damascus sword blades, and likewise for producing their toughness and elasticity of temper. The process of preparing the alloy is thus described: zinc 80 parts, purified nickel 16 parts, silver 4 parts = 100 parts. These are put into a black lead crucible, and covered with charcoal; the lid is then luted down to prevent evaporation, and exposed to the heat of an ordinary steel furnace, until the metals are fused, when the alloy is poured out into cold water, to suddenly cool it, which renders it so brittle, that it is easily reduced afterwards, by a pestle and mortar, to powder, which the patentees call *meteor powder*, and is incorporated with the steel, together with other mixtures, in the manner following: 28lbs. of common blistered steel, 10 oz. of meteor powder, 7 oz. of powdered chromate of iron, 1 oz. of charcoal, 2 oz. of quick-lime, and 3 oz. of porcelain clay, are put together in a crucible, and fused in a cast-steel furnace. After casting, this alloy is to be drawn out, under a hammer, into bars, when it will be found to exhibit the damask wavy appearance on its surface. To bring out the damask more fully upon any article made of this alloy, the surface is to be polished, and then washed over with nitric acid, diluted with nineteen times its weight of water. It could hardly have been supposed by the patentees that such a variety of substances was necessary to producing the damask pattern upon steel; the nickel and the chromium were probably introduced by them with the view of imitating those natural phenomona called meteoric stones, in which it is said one or both of these metals are constantly found: and as two or three of the other ingredients of this patent steel mixture may be regarded as fluxes, it is not quite so whimsical a compound as it might at first appear, especially as it was introduced at a time when the public taste for steel-extraordinary was so much excited.

Wootz.—This celebrated steel is made in India, at little furnaces supplied with air by several pairs of small bellows, worked assiduously by men and boys; and thus is produced the raw material of the famed Damascus sword blades, the various patterns upon which have been imitated in our linen manufacture, and hence called *damask*. To ascertain the cause of this beautiful appearance has given rise to a good deal of investigation, and several of our chemists, as well as others on the continent, have entered upon the inquiry. The wootz imported from Bombay is in form of a round cake about 2 lbs. weight. Dr. Pearson, in an essay published many years ago in the *Philosophical Transactions*, Vol. XVII., gave it as his opinion that it is made direct from the ore, and, consequently, that it has never been in the state of wrought iron. "For the cake," he says, "is evidently a mass which has been fused; and the grain of the fracture is what I have never seen in cement steel before it is hammered or melted." This opinion consists with the composition of wootz; for it is obvious that a small portion of oxide of iron might escape metallization, and be melted with the rest of the matter. The cakes appear to have been cut almost through, while white hot, at the place where wootz is manufactured; and as it is not probable that it is then plunged in cold water, the great hardness of the pieces imported above that of our steel must be imputed to its containing oxide, and, consequently, oxygen. The particular uses to which wootz may be applied may be inferred from the preceding account of its properties and composition. A very general opinion is, that the waved appearance is produced by an intermixture of steel and iron forged together, an opinion that is in some degree founded upon experiment, as very close resemblances have been made by that process. Many sword blades, in no respect inferior to the Eastern originals, have been fabricated in the dominions of Austria and Prussia, by a process invented by Professor Crevilli, who had given detailed instructions for their manufacture in a small treatise published at Milan, and entitled, *Memoria sull' Arte di fabbricare le Sciabole di Damasco.*

An epitome of Crevilli's treatise was published in the *Allgemaine Militar Zeitung*, the following translation of which was given in a recent number of the *United Service Journal*. "A long flat piece of malleable steel, of about one inch and a half in breadth, and one-eighth in thickness, is to be first bound with iron wire, at intervals of one-third of an inch. The iron and steel are to be then incorporated by welding, and repeated additions (10 or 20) of iron wire made to the first portion, with which they must be firmly amalgamated. This compound material is then to be stretched and divided into shorter lengths, to which, by the usual process of welding, grinding, and tempering, any wished-for form may be given. By filing semicircular grooves into both sides of the blade, and again subjecting it to the hammer, a beautiful roset-shaped Damascus is obtained: the material can be made to assume any other form. The solution by which the figures are made visible, is the usual one of aquafortis and vinegar. The success of this method, and the excellence of the blades which have been constructed according to these directions, have, by various trials, been placed beyond all doubt. Professor Crevilli has had several sabre blades prepared under his own instruction at Milan; similar experiments have, by the Emperor's commands, been made at the Polytechnical Institution at Vienna; and finally, the War Office has empowered Daniel Fischar, manufacturer of small arms in that capital, to proceed with the manufacture on a large scale. These blades, which, when made in large quantities, are but little dearer than those in common use, have been submitted to the severest tests. . . . . An idea of their extraordinary tenacity may be formed from the fact, that out of 210 blades that were examined by a military commission, and each of which was required to bear three cuts against iron, and two against a flat wooden table, not a single one snapped, or had its edge indented. In Prussia this method of preparing sword blades is stated to have been in practice several years, and to have been attended with equal success." M. Breant, examiner-general of assays at the Royal Mint of Paris, investigated the nature and composition of wootz very philosophically. In an interesting memoir which he published on this subject, he observes, that if in the preparation of ordinary steel sufficient carbon has not entered, the steel formed will only be in proportion to the quantity of combined carbon, the rest will be iron, only mixed. The cooling then takes place slowly, the more fusible particles of steel will tend to unite together and separate themselves from the portion of iron. This alloy will therefore be capable of developing a damask, but this damask will be white, and slightly marked, and the metal will not be susceptible of great hardness, because it will be mixed with iron. If the proportion of charcoal be exactly such as it ought to be in order to convert the whole of the iron into steel, there will be only one sort of combination; but if the carbon is a little in excess, the whole of the iron will in the first place be converted into steel, afterwards the carbon remaining in the crucible will combine in a new proportion with the part of the steel already formed. There will in this case be two distinct compounds, namely pure steel, and carburetted steel, or cast-iron. These two compounds, at first mixed confusedly, will tend to separate when the liquid matter remains at rest. A crystallization will then form, in which the particles of the two compounds will arrange themselves according to their respective affinity or specific gravity. If a blade made of this steel be put into acidulated water, a very apparent damask will be developed, in which the pure steel parts will be black, and those of carburetted steel will remain white. The carbon irregularly dispersed in the metal, and forming two distinct combinations, is, then, that which occasions the damask; and it is obvious that the slower the cooling, the larger the veins of the damask should be.

"Plumbago," says M. Breant, "has appeared to me in some circumstances to soften the steel, which an excess of carbon would render too harsh; at least I have obtained excellent results with a hundred parts of steel, one of smoke-black, and one of plumbago. But a very remarkable experiment in regard to the advantage which may be derived from it, in working on a large scale, is, *that a hundred parts of soft iron, and two of smoke-black, melt as easily as common steel*." From this announcement by M. Breant, it appears, that he was

unacquainted with Mr. Mushat's patent process of converting malleable iron into steel by fusion with charcoal, described at page 787. M. Breant continues, "It must be supposed that the whole of the carbon does not enter into combination. *Some of our best blades are the product of this combination.* It is evident from this experiment that it is not necessary, in order to obtain very good steel, to begin the operation by cementation with iron. The iron may be treated immediately with the smoke-black, and this would greatly diminish the expense of the manufacture. A hundred parts of the filings of very grey cast-iron, and a hundred parts of similar filings previously oxidized, have produced a steel of a fine damask, and fit for the manufacture of bright arms; it is remarkable for its elasticity, a quality not possessed by the Indian steel. The more carbon the steel contains, the more difficult it is to forge. Most of the specimens that I have prepared have not been drawn out, but at a temperature the limits of which are extremely confined." "I am convinced from experience, that the orbicular veins called *ronces* by the workman, which are seen on fine oriental blades, are the result of the manner of forging. If we content ourselves with drawing the steel out lengthwise, the veins will be longitudinal; if we extend it equally in all directions, the damask has a crystalline appearance. If we render it wavy in the two directions, there will be shades and gradations as in the oriental damask. It will not require long trials to produce any variegated design we desire."—*Repertory of Arts.*

Having explained the most approved modes of preparing the celebrated damasked steel, as well as the various steels of our now no less celebrated British manufacturers, we proceed to the consideration of another department of the subject.

Case-hardening.—This is a process for converting the surface only of articles made of malleable iron into steel, in order that they may afterwards receive a high polish. The process is extensively applied to the pokers, tongs, and shovels of our domestic fire-grates, and to an infinite variety of our iron manufactures. The following mode, recommended by Mr. Gill, editor of the *Technological Repository,* deserves confidence, from the extensive practical knowledge of that gentleman in the treatment of iron and steel. This is effected, he says, by inclosing the articles in carbonaceous compounds, either animal or vegetable, and exposing them to heat in close vessels, until the change is completed, and until the surface at least of the articles is converted into steel. For this purpose, bones, from which the ammonia has been extracted by distillation at a high temperature, and which are afterwards ground to a coarse black powder, are chiefly used. The articles being surrounded with this powder, contained in cast-iron vessels, are exposed to a high red heat, in an open fire-place, for several hours, until the surfaces of the iron articles are sufficiently changed to steel; when, if large enough, they may be taken out, whilst hot, and quenched in water, or if too small and numerous, the whole contents of the vessel, bone-dust and all, may be poured into the water. Any parts of the articles which are required to remain *iron* after this operation, may be guarded from the action of the carbon, by coating them with clay or loam. Sometimes the water is covered with a layer of oil, two or three inches in depth, to prevent the small steel articles from being cracked in quenching; and it is very convenient in this case to have a wire sieve suspended in the water, at a proper depth beneath its surface, to suffer the bone ashes to fall through, but to detain the small articles. Other substances are employed in case-hardening; leather, burnt till it can be pulverised, is considered a good agent; also the hoofs and horns of animals, heated in an oven until they can be beaten to a coarse powder: the latter are preferred by gunsmiths for their work.

Hardening and Tempering.—In giving the requisite degree of hardness to cutting instruments of steel, two distinct processes are employed; first, hardening, and afterwards tempering. The hardening is effected by heating the steel to a cherry-red, and immediately plunging it into cold water; by this process, the steel becomes so hard as to resist, or turn the edge of the hardest file; likewise so brittle as to be useless for most purposes, but particularly for cutting instruments. To adapt the steel to the latter, the second process, called tempering,

is resorted to, which is a species of annealing, or softening, or as the workmen term it, *letting down*, to the degree of hardness which is necessary for the peculiar purpose for which it is designed; for in proportion as the edge is harder than is required, is its liability to break in use. It is a remarkable fact, that the greatest part of our ordinary cutlery is hardened by a process which, although well known to be a very defective one, is persisted in from the force of habit, or from an indisposition in the workman to make any changes in the customary routine of executing work, in which the remunerating prices are very low. We allude in particular to the practice (which, we are informed, is general at Sheffield,) of hardening direct from the anvil; that is, the articles are hardened with the scale on the surface, which is produced by the act of forging. The scale varies in thickness, according to the degree of heat the steel received in forging; it is also a very bad conductor of heat, consequently the transition from heat to cold (by which the effect of hardening is produced) is not so sudden in one piece of steel as in another; and some are scarcely hardened at all, owing to the temperature of the water having scarcely penetrated through the scale. Hence, when such articles are afterwards tempered or "lowered," there are not two alike in temper out of a great number; a fact which can hardly have escaped the observation of any man who has shaved for several years. Instead, therefore, of the customary mode of hardening the blade direct from the anvil, it has been recommended by an experienced manufacturer, that the blades be passed from the anvil to the *grindstone*. "A slight application of the stone," he observes, "will remove the whole of the scale or coating, and the razor will then be properly prepared to undergo the operation of hardening with advantage. It will be easily ascertained that steel in this state heats in the fire with great regularity, and that when immersed, the obstacles being removed to the immediate action of the water on the body of the steel, the latter becomes equally hard from one extremity to the other. To this may be added, that as the lowest possible heat at which steel becomes hard is indubitably the best, the mode here recommended will be found the only one by which the process of hardening can be effected with a less portion than is or can be required in any other way."

Considerable difficulty has been experienced in giving to articles about to be hardened a perfectly uniform degree of heat in an ordinary fire; and one of the best means of obviating it is probably that which has been published by Mr. Nicholson, of his adoption, and which he had for some time previous, for justifiable reasons, kept secret: this was to employ a bath of melted lead, heated to moderate redness, and well stirred; into this the piece was plunged for a few seconds, until, when brought near to the surface, that part did not appear less luminous than the rest. The piece was then speedily stirred in the bath, suddenly drawn out, and plunged into a large body of water. Instead of employing simple water as the cooling medium, a variety of salts added to it have been at different times recommended and boasted of. Not long ago, mercury was cried up, and just now it is the fashion to extol a current of air, grounded, we believe, on the report of travellers, that the sabres of Damascus are hardened by cleaving the north wind with them. Although it is probable that improvements in the present mode of hardening may be discovered, we think it is improbable that they will be found in that fluid which is an inferior conductor of heat, and that cannot be applied with equal uniformity to water.

A mode of tempering instruments of hardened steel was invented by Mr. Hartley, in 1789, for which he obtained a patent; and we have never yet heard of a better. Mr. Hartley's plan was to immerse the articles in a bath of oil, heated to a regulated temperature, and measured by a thermometer. This was certainly a very great improvement, both in point of precision and dispatch, on the common method of heating the instrument over a flame till a certain colour, produced by a film of oxide, appears on its surface. These colours are—

At 430° Fah. a very faint yellow,—for lancets.
450° „ a pale straw colour,—for razors, and surgeons' instruments.
470° „ a full yellow,—for penknives.

At 490° Fahr. a brown colour,—for scissors and chisels for cutting old iron.
510° „ a brown, with purple spots,—for axes and plane irons.
530° „ a purple,—for table-knives and large shears.
550° „ a bright blue,—for swords, watch springs, truss springs, and bell springs.
560° „ a full blue, for small fine saws, daggers, &c.
600° „ a dark blue, verging on black,—is the softest of all the gradations, when the metal becomes fit only for hand and pit-saws, which must be soft, that their teeth may bear sharpening by the file, and bending or "setting."

If the steel be heated still further, it becomes perfectly soft. When tools having a thick back and thin edge, like penknives, are to be tempered, they are sometimes placed with their backs in a plate of hot iron, or on hot sand; otherwise they would become too soft at their cutting edges before their backs would be sufficiently heated. It is evident that baths of any of the soft metals, whose fusible points are above those required for tempering, may be used instead of oil; and alloys of those metals might be so proportioned as to obtain points of fusion at the exact degree of heat required. In these cases, however, to prevent oxidation, it would be necessary to keep the fluid metal covered with grease, and it would be advisable not to omit the use of a thermometer. Mr. Gill, in the *Technological Repository*, has recommended several compositions for hardening and tempering steel, to which work we must refer the reader for the formulæ and processes. We do not insert them here, because they are, for the most part, apparently unsuited to operations on the great scale, although they are certainly, in many respects, well deserving the attention of engineers. We shall, however, avail ourselves of his instructions in the following article.

On restoring the Elasticity of hardened and tempered Steel Articles.—"Saws, sword-blades, clock and watch springs, &c., which, after being hardened and tempered, require to be ground and polished,or otherwise brightened, lose their elasticity or springiness by these operations, so as to appear soft on bending them, although they are as hard as ever; these qualities are again restored to them, either by heating over a clear fire, made of cinders urged by bellows, or over the flame of burning alcohol, or by inclosing them in a smouldering fire, made of wood-ashes and embers, to a blue colour, which colour may either remain, or be removed by the application of diluted muriatic acid wiped over them."

The partial Conversion of Iron into Steel, which is often the case in the blistered bars, owing to the carbon not having penetrated to the middle, is usually regarded as a great defect; but an important advantage may be gained from it in the steeling of edge-tools, which, Mr. Gill says, is adopted by Mr. Maudsley. The bar is split down its middle into two parts, and these parts are sometimes subdivided; the internal parts which remain unconverted are then welded to the iron of the tool, leaving the steel outside, to form the cutting edges of the tool.

TABLE,—*Showing the Weight of Cast-iron Plates, twelve inches wide, and from one-eighth of an inch to one inch thick.*

Width in Inches.	PARTS OF AN INCH IN THICKNESS.															
	$\frac{1}{8}$		$\frac{1}{4}$		$\frac{3}{8}$		$\frac{1}{2}$		$\frac{5}{8}$		$\frac{3}{4}$		$\frac{7}{8}$		One Inch.	
	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.
12	4	$13\frac{3}{8}$	9	$10\frac{5}{8}$	14	8	19	$5\frac{3}{8}$	24	$2\frac{3}{4}$	29	0	33	$13\frac{3}{8}$	38	$10\frac{3}{4}$

TABLE,—*Showing the Weight of one Foot Length of Malleable Iron.*

SQUARE IRON.		ROUND IRON.			
Scantling.	Weight.	Diameter.		Circumference.	
Inches.	Pounds.	Inches.	Weight in Pounds.	Inches.	Weight in Pounds.
¼	0.21	¼	0.16	1	0.26
⅜	0.47	⅜	0.37	1¼	0.41
½	0.84	½	0.66	1½	0.59
⅝	1.34	⅝	1.03	1¾	0.82
¾	1.89	¾	1.48	2	1.05
⅞	2.57	⅞	2.02	2¼	1.34
1	3.36	1	2.63	2½	1.65
1⅛	4.25	1⅛	3.33	2¾	2.01
1¼	5.25	1¼	4.12	3	2.37
1⅜	6.35	1⅜	4.98	3¼	2.79
1½	7.56	1½	5.93	3½	3.24
1⅝	8.87	1⅝	6.96	3¾	3.69
1¾	10.29	1¾	8.08	4	4.23
1⅞	11.81	1⅞	9.27	4½	5.35
2	13.44	2	10.55	5	6.61
2¼	17.01	2¼	13.35	5½	7.99
2½	21.00	2½	16.48	6	9.51
2¾	25.41	2¾	19.95	6½	11.18
3	30.24	3	23.73	7	12.96
3½	41.16	3¼	27.85	7½	14.78
4	53.76	3½	32.32	8	16.92
4½	68 04	3¾	37.09	8½	19.21
5	84.00	4	42.21	9	21.53
6	120.96	4½	53.41	10	26.43
7	164.64	5	65.93	11	31.99

END OF VOL. I.

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